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SPEECH UNDERSTANDING RESEARCH

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I INTRODUCTION

For two and a half years, Stanford Research Institute has been participating with other ARPA/IPT contractors in a major program of research on the analysis of continuous speech by computer. The goal is the development, over a five-year period, of a speech understanding system capable of engaging a human operator in a natural conversation about a specific task domain.* During the first year of the SRI project, the domain chosen provided interactions with a simulated robot that knew about and could manipulate various kinds of blocks. The system implemented during this period made major use of procedures developed by Winograd (1971) for understanding sentences in natural language entered as text.**

During the second year of the project, a new task domain was chosen: the assembly and repair of small appliances, beginning with a leaky faucet. This change was made to provide for more complex interactions of a user with the system, involving a sequence of subtasks. Major modifications were made in all parts of the system, the most important of which was the development of a new parsing strategy. A description of this second version of the SRI speech understanding system is the primary content of this report.*** Section II contains a description of the structure of the current system. Section III describes the processing involved in the analysis of an utterance. Section IV presents the data available on system performance.

Recently, and in accordance with the recommendations resulting from the mid-course evaluation of the Speech Understanding Research Program, SRI has begun collaboration with the System Development Corporation on the development of

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*See Newell, et al. (1973) for the recommendations of a study group that led to the establishment of this program. The report also contains specifications of the parameters for the target systems. References are located after Section V.

**See the First Annual Technical Report (Walker, 1973a) for a description of these initial efforts; also see Walker (1973b), a copy of which is included as an attachment to this Report.

***See Walker (1973c) for a perspective on the transition from the first to the second versions of the system; Walker (1974) consists primarily of material from Sections II and IV; copies of each are attached.

a joint system that will combine features and components of the previous systems developed by each contractor. The initial steps in this effort are described in Section V.

Papers prepared under this project are included as attachments to this Report.

II THE STRUCTURE OF THE CURRENT SYSTEM

A. System Concept

The structure of the SRI speech understanding system is presented in Figure 1. Information from various sources of knowledge is coordinated by the parser to predict the sequence of words in an utterance spoken in the context of a particular task domain. On the basis of this information, a priority is assigned to each path branching from the current choice point in the grammar. In following a path, when a word is predicted for a particular place in the utterance, a word function is called. Each word function contains a representation of the acoustic features of that word based on its pronunciations in a variety of contexts. A test of the particular word function against acoustic data from the utterance returns a priority for assuming that the word is present. This value is part of the information used to decide which path to follow next. A complete analysis of an utterance produces a program that operates on a model of the world corresponding to the task domain. The execution of the program constitutes the "understanding" of the utterance; then, an appropriate response is made.

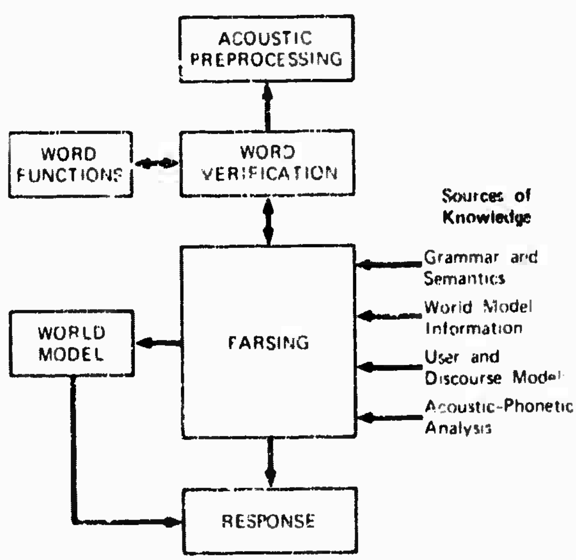

FIGURE 1 STRUCTURE OF THE SRI SPEECH UNDERSTANDING SYSTEM

B. Task Domain

The task domain for the current system is a simulation of the actions required for assembly, test, and repair of small mechanical devices. The initial task is repairing a leaky faucet. Some additional information about this "faucet world" is presented in subsection 4 under World Model.

C. Basic System Components

1. Acoustic Preprocessing

An utterance is recorded in a double-walled IAC booth, using a 1-inch condenser microphone and a studio-quality tape recorder. The signal is bandpass-filtered at 80-80,000 Hz by an active 70 dB/octave filter; it is then digitized at 20,000 sps with an 11-bit quantization, providing a signal-to-noise ratio of about 40 dB. The digitized wave form is monitored on a CRT for excessive peak clipping or underusage of dynamic range. The digitization is performed on a PDP-11, and the results are transferred by DEC-tape to the PDP-10 for the next steps (an interim expedient).

a. Classification. The raw signal plus the outputs from four digital filters (80-200 Hz, 300-1000 Hz, 500-2800 Hz, and 3200-6800 Hz) are used to classify each 10-ms interval as vowel-like, voiced stop, voiced turbulence, unvoiced turbulence, silence, or transient/unknown. Three other digital filters (1500-8000 Hz, 1500-3000 Hz, and 4000-8000 Hz) are used to classify turbulent intervals as s, sh, f-th, z, zh, or v-dh. The algorithms used for classification are presented in Becker and Poza (1974), a copy of which is attached to this Report.

b. Spectral Analysis. An LPC analysis of the voiced intervals provides frequency and half-bandwidth values for the first five formants. The LPC is performed over a 15-ms interval, using 3 dB/octave preemphasis, 26 coefficients, a Hamming window, and 128 estimation points in the frequency continuum.

2. Word Functions

A word function is prepared after a detailed examination of acoustic data for that word in selected contexts from a variety of utterances. Judgments are made about the acoustic parameters that are most relevant and the variations in the parameters that are most reasonable. Each word function consists of a series of FORTRAN subroutines that use data from a variety of sources: the acoustic preprocessing

of the utterance; algorithms for level (volume) detection, formant smoothing, detecting formant discontinuities, fitting formant trajectories, and identifying formant bandwidths; and specially designed digital filters or LPC analyses.

Spectrograms and the results of acoustic preprocessing are available for almost 300 utterances. When the interactive speech analysis system is used (see Walker, 1973a, for a description), a graphic display of these results can be seen for each utterance: specifically, the classification of 10-ms intervals, the positions of each of the first three formants, and an indication of places in the utterance where changes in level are detected. A photograph of the display developed on transparent acetate and overlaid on a spectrogram of the utterance provides a permanent form that can be photocopied for ease in handling. A more detailed representation of the acoustic information is available in printouts containing all of the data determined for each 10-ms interval during acoustic preprocessing. Both kinds of data are presented for the utterance whose processing by the system is examined in detail in Section III.

The data base also can be processed by an interactive program exerciser that can produce the values of any specified parameters for portions of those utterances in the data base that contain occurrences of a particular word. In addition, it is possible to test out the various algorithms, digital filters, or special LPC analyses over these same intervals.

On the basis of these sources of information, decisions are made about the analysis techniques to use in a word function, their order of application, and the appropriate parameters. The exerciser then is used to test the word function against utterances in the data base to determine where it succeeds and fails. Threshold changes can be made on line, interactively in the exerciser; or other analysis techniques can be selected and the exerciser run again. Forty-two word functions are currently available.

A more detailed description and evaluation of phonetic and phonological analysis through word functions is presented in a paper by Becker and Poza (1974), a copy of which is included as an attachment to this Report.

3. Parsing

The parser performs a dual role. In addition to handling the usual parsing functions, it calls on the other components and coordinates information from them.

The parser executes a top-down, "best-first" strategy. Each new path resulting from a choice point is assigned a priority according to its estimated likelihood of arriving at a correct parse. These paths are added to the set of all possible paths created but not yet extended during the parse. The system follows the highest priority path until its priority drops or a choice point is reached. At this time, the cycle repeats. When the highest priority path requires testing for the presence of a particular word, the appropriate word function is called. A complete analysis of an utterance produces a program that references procedures and data in the world model.

Several sources of knowledge currently affect the value of a priority: the grammar (parameters are assigned to alternative branches at a choice point, reflecting our judgment about their relative likelihood), the world model, and the results of the word function test.

The basic programs for the parser are written in INTERLISP, but an interpreter has been added to handle multiprocessing control structures and to facilitate sharing information among the competing processes looking for a parse. A single family of processes acts as the sole producer of certain constructions (currently just simple noun phrases); processes needing such constituents provide the contexts for establishing priorities within the family and act as consumers of structures produced by it.

A debugging facility for the multiprocessing control structures has been developed and integrated into the standard LISP debugging package. It allows us to trace the overall parse, to check the history of various processes, and to establish break points in the grammar.

The operation of the parser is described in more detail in Section III and in papers by Paxton and Robinson (1973) and Paxton (1974), copies of which are included as attachments to this Report.

4. World Model

The world model contains data reflecting the current configuration of objects in the task domain and procedures for operating on that configuration. The program resulting from a completed parse will contain references to specific objects corresponding to definite descriptions (definite noun phrases and proper nouns), procedures for finding objects satisfying indefinite descriptions (other noun phrases), and procedures for testing or establishing relations (given by verbs and prepositions). Executing the program for an

imperative produces a description of actions performed in carrying out that command. Executing the program for an interrogative produces a set of objects satisfying the queried relation.

The faucet world contains a faucet, screws, washers, tools, and other objects relating to plumbing. The objects can be of different sizes and colors; their locations, type, and condition can be specified. Class membership, superset relations, and various kinds of connections among the objects are possible. A variety of actions can be performed that entail moving, picking up, screwing, unscrewing, and the like.

The current implementation in QLISP (see Reboh and Sacerdoti, 1973) provides capabilities for updatable model manipulation, including associative storage and retrieval of procedures and data.

5. Response

The response of the system depends on the form of the utterance, the state of the world, and the result of executing the program. For imperatives, the system simply lists the actions performed. For interrogatives, the type of the question determines the general form of the response. For example, a "how many" question is answered by giving the size of the answer set returned by the program for the utterance and then describing the members of that set. In forming a description of the objects, the world model is used to find identifying properties (such as size, color, and type), and the utterance phrase corresponding to the object (e.g., 'What bolt?') is used to form a natural abbreviation (e.g., 'The small one.'). Currently, responses are typed out on the terminal.

D. Sources of Knowledge

1. Grammar and Semantics

The grammar contains clause, noun-group, and verb-group subgrammars, and a case component. The clauses are: major (declarative, imperative, and question); adjunct; sentence complement; and noun-qualifying. The verb-group subgrammar allows: present and past tense, active and passive voice, and auxiliary preceding or separate from the main verb. The noun-group subgrammar allows: determiner, quantifier, adjective, noun, pronoun, qualifying phrase, and qualifying clause. In the case component, verb functions establish for each verb sense its obligatory and optional

cases--causal actant, instrument, theme, locus, source, goal, loc, and time. Each verb function calls a paradigm that specifies the allowable clause positions for the different case arguments and maps these arguments into a goal state to be achieved in the world model.

The current vocabulary can handle 54 words, including 11 plural and five past tense forms. (This number is determined by the number of word functions written; there are syntactic and semantic specifications for almost 300 words.) Each entry can include word type, syntactic and semantic features, a call to the paradigm (for verbs), a function for resolving anaphoric reference, information specifically related to the world model, a function for evaluating its priority, and a call to its acoustic word function. Currently, we can handle anaphora for pronouns (e.g., 'it' and 'one') and for definite noun phrases that are in case arguments in the main clause of the sentence. A discussion of some of the semantic and pragmatic processing in the system is described in Baranofsky (1974); a copy is included as an attachment to this Report.

2. World Model Information

In addition to its role as a basic system component, the world model functions as a source of knowledge to affect the value of priorities in the parsing. At present, its use in this role is to determine whether definite noun phrases or prepositional phrases correspond to some portion of the model. Paxton (1974) provides a detailed discussion of the procedures involved.

The presence of a model of the task would be a valuable addition. Therefore, toward this goal, we have specified the sequences of steps involved in repairing a faucet that has a worn washer, but this information has not been incorporated into the world model.

3. User and Discourse Models

A user of the system is presumed to be task-oriented, in a quiet room, and speaking in a clear, "normal" manner without repetitions or noisy hesitations. Currently, threshold parameters in the word functions are adjusted for the voices of two different speakers; in only a few cases has it been necessary to provide different values for each. To extend the system to larger numbers of users, speaker-dependent information would have to be incorporated for adequate discrimination.

The person using the system is assumed more likely to use certain constructions. The initial parameters for the priorities of different rules in the grammar are set according to our intuitions about these likelihoods. However, we recognize the need to model the discourse more accurately; for example, the parameters should vary depending on progress in the performance of the task. Consequently, we have been conducting protocol experiments to gather data about the form and sequence of the utterances likely to occur in dialogs with the system. See Deutsch (1974) for a more extended discussion; a copy is included as an attachment to this Report. Eventually, it may be possible to incorporate speaker- dependent information about the relative frequencies of use of different constructions. Robinson (1974) provides an extended discussion of linguistic performance that is clearly relevant to modeling differences among speakers; a copy of her paper is included as an attachment to this Report.

4. Acoustic-Phonetic Data

Prosodic information can be critically important in a system of this design. Accordingly, we have collected data from the protocol experiments to use to correlate intonation cues with sentence type, to relate stress cues to the distinction between old and new content elements in the dialog, and to identify phrase boundaries within an utterance. Our studies of utterances parsed by the system indicate clearly that this information would increase the efficiency of the analysis.

III THE ANALYSIS OF AN UTTERANCE

A. Introduction

This description of the analysis of an utterance will be concerned primarily with the acoustic preprocessing and parsing steps. The utterance to be examined is 'What little brass parts are in the box?' Reference to the papers by Becker and Poza (1974), Paxton and Robinson (1973), Paxton (1974), and Baranofsky (1974), all of which are included as attachments to this Report, will provide more detailed analyses of the underlying procedures.

B. Acoustic Preprocessing

As described in Section II, the initial acoustic processing of an utterance provides two kinds of information for each 10-ms segment of the utterance. First, a segment is classified as one of ten categories on the basis of data provided by two sets of digital filters. The alternatives are vowel-like, voiced stop, s, sh, f-th, z, zh, v-dh, silence, and transient/unknown. Second, an lpc analysis provides frequency and half-bandwidth values for the first five resonance peaks. For voiced segments, these values can be used in the identification of formants; the data gathered for other kinds of segments are not used.

Table 1 shows the classification of the first 30 ms of the example utterance, together with the data from the first set of digital filters. The INT column identifies successive 10-ms intervals. CL shows the classification of the interval: SI for silence, VS for voiced stop, V for vowel-like. The first column under RAW contains the rms-values for the unfiltered signal; all the other columns contain dB values, normalized so that the highest value in each column is 0.0. Table 2 presents the LPC data for the same intervals. The column labeled RMS contains the normalized dB values provided by the LPC analysis; they correspond to the dB values in Table 1 under RAW, differing because of the interval of time over which they are computed. Appendix A contains the complete result file from the acoustic preprocessing of the example utterance.

The results of the acoustic preprocessing can be represented graphically. Figure 2 shows a spectrogram of the example utterance. Figure 3 shows the spectrogram overlaid with a photograph on acetate of the results on an Adage display terminal. The first three peaks are shown for

Table 1

ACOUSTIC PREPROCESSING FOR THE FIRST 30 MS OF THE UTTERANCE 'WHAT LITTLE BRASS PARTS ARE IN THE BOX?': CLASSIFICATION WITH DIGITAL FILTER OUTPUT

DIGITAL FILTER OUTPUT

INT	CL	RAW		VOICE	LOW	MID	HIGH
1	SI	2.	-43.0	-50.0	-50.0	-50.0	-40.3
2	SI	2.	-43.8	-42.4	-50.0	-50.0	-41.2
3	SI	1.	-47.7	-41.2	-50.0	-50.0	-40.3
4	SI	3.	-41.7	-43.6	-50.0	-50.0	-39.6
5	SI	2.	-47.1	-45.9	-50.0	-50.0	-41.0
6	SI	2.	-44.6	-45.7	-50.0	-50.0	-40.7
7	SI	3.	-42.1	-40.7	-50.0	-50.0	-39.8
8	SI	5.	-37.0	-36.5	-50.0	-50.0	-40.4
9	SI	10.	-30.7	-30.0	-46.4	-50.0	-40.9
10	VS	30.	-21.3	-21.6	-35.2	-44.3	-40.1
11	V	150.	-7.3	-9.8	-15.5	-23.1	-37.3
12	V	172.	-6.1	-5.7	-7.7	-14.1	-31.0
13	V	2[illegible]4.	-4.2	-5.1	-4.7	-11.5	-27.3
14	V	206.	-4.6	-5.3	-7.1	-11.4	-21.8
15	V	263.	-2.4	-4.5	-4.6	-7.0	-16.6
16	V	235.	-3.4	-3.7	-3.1	-5.5	-15.2
17	V	296.	-1.4	-3.1	-2.6	-3.4	-13.2
18	V	348.	0.0	-3.3	0.0	-1.4	-8.9
19	V	307.	-1.1	-4.2	-0.3	0.0	-11.3
20	V	286.	-1.7	-5.3	-2.6	-2.4	-7.3
21	V	183.	-5.6	-6.2	-5.3	-5.0	-11.5
22	V	108.	-10.2	-7.3	-17.6	-19.0	-20.4
23	VS	72.	-13.7	-11.5	-22.5	-29.3	-39.3
24	V	102.	-10.7	-10.0	-18.5	-27.6	-27.3
25	VS	111.	-9.9	-7.8	-18.7	-27.0	-34.4
26	VS	146.	-7.5	-7.2	-16.8	-26.3	-35.6
27	V	136.	-8.1	-5.5	-12.7	-23.8	-36.0
28	V	187.	-5.4	-4.1	-11.0	-21.8	-34.9
29	V	175.	-6.0	-3.1	-10.3	-22.5	-32.4
30	V	208.	-4.5	-2.6	-10.0	-21.4	-31.5

Table 2

ACOUSTIC PREPROCESSING FOR THE FIRST 30 MS OF THE UTTERANCE 'WHAT LITTLE BRASS PARTS ARE IN THE BOX?': CLASSIFICATION WITH "FORMANT" FREQUENCY AND HALF-BANDWIDTH VALUES

		LPC "FORMANT" PEAKS						LPC HALF-BANDWIDTH VALUES				
INT	CL	F1	F2	F3	F4	F5	RMS	B1	B2	B3	B4	B5
1	SI	117.	1131.	1989.	2613.	3432.	-18.0	0.0	0.0	0.0	0.0	0.0
2	SI	975.	1833.	2769.	3588.	4446.	-17.7	0.0	0.0	0.0	0.0	0.0
3	SI	1014.	1716.	2301.	3276.	4095.	-16.6	0.0	0.0	0.0	0.0	0.0
4	SI	1014.	2067.	2652.	3315.	4212.	-17.4	0.0	0.0	0.0	0.0	0.0
5	SI	936.	1950.	3471.	4212.	5148.	-18.5	0.0	0.0	0.0	0.0	0.0
6	SI	390.	1716.	2379.	3471.	4212.	-17.8	0.0	0.0	0.0	0.0	0.0
7	SI	853.	1872.	3393.	4212.	4836.	-17.6	0.0	0.0	0.0	0.0	0.0
8	SI	1131.	1911.	2964.	3471.	4329.	-18.5	0.0	0.0	0.0	0.0	0.0
9	SI	234.	1092.	2028.	2847.	3568.	-17.7	0.0	0.0	0.0	0.0	0.0
10	VS	273.	1872.	2691.	3822.	4173.	-14.8	153.2	272.3	213.9	255.0	282.8
11	V	351.	702.	2886.	4797.	5499.	-7.6	61.1	153.2	136.6	224.2	133.3
12	V	429.	780.	2847.	3276.	4485.	-6.7	93.7	123.3	54.6	87.1	234.4
13	V	429.	702.	2808.	3198.	4563.	-5.1	74.1	183.4	41.7	126.6	356.7
14	V	429.	819.	2808.	3198.	5577.	-5.5	100.2	186.8	64.3	133.3	328.3
15	V	507.	936.	2769.	3198.	3549.	-3.5	77.3	87.1	48.1	110.1	139.9
16	V	546.	1014.	2769.	3276.	3666.	-2.9	67.0	67.6	57.8	120.0	163.3
17	V	585.	1053.	2730.	3276.	3666.	-2.0	54.6	38.4	28.8	106.8	106.8
18	V	585.	1092.	2730.	3354.	3744.	-0.9	54.6	70.8	100.2	103.5	87.1
19	V	585.	1170.	2769.	3432.	3822.	-1.0	38.4	35.2	113.4	97.0	110.1
20	V	585.	1209.	2223.	3081.	3627.	-1.5	67.6	19.2	244.7	54.6	53.9
21	V	546.	1209.	3003.	3861.	5772.	-3.0	77.3	19.2	44.9	123.3	227.6
22	V	312.	1131.	2964.	3978.	4680.	-9.6	83.9	44.9	64.3	170.0	210.5
23	VS	234.	1209.	3003.	3900.	4797.	-11.8	44.9	100.2	106.6	103.5	202.0
24	V	273.	1170.	2106.	2925.	3822.	-9.9	22.4	106.8	54.6	173.3	193.6
25	VS	312.	1092.	2028.	3042.	3705.	-9.6	25.6	28.8	170.0	234.4	103.5
26	VS	312.	1092.	2223.	2886.	3627.	-9.4	28.8	28.8	173.3	353.1	77.3
27	V	312.	1053.	2145.	3081.	3744.	-8.6	28.8	32.0	143.2	200.3	203.7
28	V	312.	1092.	2145.	3159.	3666.	-7.8	16.0	28.8	170.0	340.0	265.4
29	V	312.	1092.	2184.	2964.	3588.	-7.8	19.2	54.6	90.4	220.7	163.3
30	V	273.	1209.	2223.	3120.	3744.	-7.3	19.2	110.1	80.6	170.0	156.6

FIGURE 2 SPECTROGRAM FOR THE UTTERANCE 'WHAT LITTLE BRASS PARTS ARE IN THE BOX?'

FIGURE 3 SPECTROGRAM OVERLAID WITH RESULTS OF ACOUSTIC PREPROCESSING FOR THE UTTERANCE 'WHAT LITTLE BRASS PARTS ARE IN THE BOX?'

vowel-like segments; as can be seen, they correspond reasonably well to the formants. Formant smoothing and the interpretation of discontinuities are done during word verification. The marks for the unvoiced portions of Figure 3 are codes that correspond to the other segment classifications. The bar at the bottom indicates silence; three closely spaced bars at the bottom indicate voiced stop; three closely spaced bars at the top indicate s; three widely spaced bars down slightly from the top indicate f-th. The arrows at the bottom of the spectrogram show changes in the amplitude of the rms output of the mid-range filter. These data actually are computed during word verification, where they are useful in determining the beginning and ending of a word and in distinguishing internal features.

C. Parsing an Utterance

The acoustic preprocessing provides the parser with the beginning and ending points of the utterance. However, parsing proceeds independently of the acoustic data until a word function is called. There are nine sections in the output provided following the parsing of an utterance:

(1) The actual sequence of steps in the parsing
(2) Some statistical data on the operation of the program
(3) A listing of the successive nodes along the successful path
(4) An identification of the utterance that the system "heard",
(5) The response of the system to that utterance
(6) The parse tree for the utterance showing its syntactic structure
(7) The values of the acoustic starting and ending points of the utterance
(8) A listing of the words that received scores other than zero in the acoustic verification steps
(9) A listing of all the words checked acoustically for their presence during the parse.

Each of these sections will be described for the utterance 'What little brass parts are in the box?' The complete trace itself is provided as Appendix B. The papers by Paxton and Robinson (1973) and by Paxton (1974) will be helpful for understanding the following description.

1. Tracing the Parse

The parsing of an utterance involves tracing through the grammar rule by rule. Decisions among the alternatives at a choice point are made on the basis of initial priorities

established for those alternatives, on the basis of priority functions called at that point, and on the basis of tests against the acoustic data to verify the presence of a particular word.

a. Kinds of Entries in a Trace. There are six different kinds of entries in a trace:

(1) The start of the parsing of some grammatical unit

ENTER PARSE CLAUSE AT LOCATION 8

The entry contains the name of the grammatical unit and its starting location (in 10-ms units) in the result file with the acoustic data for the utterance.

(2) The creation of a process

1 INITSTRING 200
2 "INITSTRING" 950

As each process is created, it is given an identification number, a name--which is the alternative to be taken in the grammar at that choice point when the process is activated, and a priority. These processes are added to the list of all processes created but not yet activated during the parse. The value of the priority is a function of the initial priority assigned to the alternative in the grammar, the priority of the path up to this point, and the results of any special priority functions called when the process is created. These special priority functions allow semantic, pragmatic, and other sources of knowledge to be used to affect the choice of paths in a parse (for details, see Paxton, 1974). The example above shows the two processes created by entering the parse of a clause (beginning at the first rule in the clause grammar): a clause may be preceded by an initial string--perhaps a sentence adverbial--or it may be the first constituent. Since the parse begins with a priority of 1000, the respective values of 200 and 950 indicate that the initial priorities for those alternatives are .2 and .95.

(3) The activation of a process

2 ("INITSTRING") 950 1

The entry for a process that is activated contains its number, its name plus the names of the two previous nodes along this path, the priority of the process, and the number of processes remaining on the process queue--that is, the ones that have been created but not yet activated.

(4) The creation of a family

17 (WHNG WHQUEST QUEST) 840 12
ENTER PARSE NGROUP AT LOCATION 8
ENTER FAMILY FOR WHNGSIMP AT LOCATION 8
NEW FAMILY CREATED

In this set of entries, Process 17 is activated; it indicates a path consisting of "question", followed by "WH-question", followed by "WH-noun group". The priority of the process is 840; there are 12 other processes on the process queue. The result of this process is entry into the noun group grammar. This step is followed by the creation of a family, a device that allows all processes looking for a noun group at a particular location to share the same information (for details, see Paxton and Robinson, 1973, and Paxton, 1974).

(5) Testing for a word in the acoustic data

26 (*WORD* BEAUX POLAR) 815 14
AC   IS 8 0.0
   26 *WORD* 815
26 (*WORD* BEAUX POLAR) 815 14
AC   ARE 8 1.125 11 22
   26 *WORD* 916

When a process calling for a word is activated, a word verification function is called (indicated by "AC"; "ACAC" is used for plurals). If the word is not present, as in the first instance, the location where the search was conducted is given, followed by "0.0". If the word is found, the subsequent entries indicate where the search started, the value of its priority (the results of the acoustic test, modified according to gap/overlay with adjacent words, as described in Paxton, 1974), and the beginning and ending points of the word as provided by the word verification function. The priority for the word multiplied by the priority for the process that called for the word yields the result shown on the last line.

(6) The end of the parsing of some grammatical unit

EXIT PARSE (WHNGSIMP WHNG QDET PLURAL)
   228 PARTS 2233 FROM 17

When parsing has been completed for a grammatical unit, it is indicated by an entry that specifies the grammatical structure of the unit parsed. If this is an exit from a family, then the next line will show a new process created, the last node, the new priority value, and the number of the process from which this parse was entered.

b. The Sequence of Steps in a Parse. In parsing an utterance, at each choice point in the grammar, the highest priority process is selected from the process queue. Consider the following set of entries taken from the beginning of the parse:

```
ENTER PARSE CLAUSE AT LOCATION 8
   1 INITSTRING 200
   2 "INITSTRING" 950
2 ("INITSTRING") 950 1
   3 DECLAR 570
   4 IMPER 912
   5 QUEST 912
5 (QUEST "INITSTRING") 912 3
   6 WHQUEST 875
   7 POLAR 875
4 (IMPER "INITSTRING") 912 4
   8 EMPHATIC 182
   9 NEG 182
   10 SIMPLE 875
10 (SIMPLE IMPER "INITSTRING") 875 6
   11 BE 175
   12 SIMP 840
7 (POLAR QUEST "INITSTRING") 875 7
   13 DOAUX 437
   14 MODALAUX 175
   15 HAVEAUX 175
   16 BEAUX 831
6 (WHQUEST QUEST "INITSTRING") 875 10
   17 WHNG 840
   18 WHPREP 175
   19 HOWADJ 175
```

The parse begins in the clause grammar, and two processes are created, as described above. The one with the highest priority (2) is run, and it creates three processes--one for declaratives, one for imperatives, and one for questions. There are now four processes on the process queue: 1, 3, 4, and 5. The one with the highest priority that was last entered is activated first. As shown in the remaining entries, the parser creates processes that extend both the question and imperative paths.

2. Statistics on Program Operation

The following data, presented in the second part of the output from the parse, were collected for the utterance:

```
6:48 RUNTIME
0:17 GCTIME
25:24 REAL TIME
```

31775 CONSES
9881 PAGE FAULTS
LOAD AV 3.2 2.93 2.54

Values in minutes and seconds are given for runtime, garbage collection time, and console time. CONS is a LISP list-building function; it indicates in a crude way the level of program activity. Similarly, PAGE FAULTS gives an overall indication of the amount of system overhead. The LOAD AV values show the level of activity in the time sharing system; the number of processes in the ready queue waiting for a processor are shown for the current time and for the last 10 minute and 30 minute periods.

3. The Successful Path

The nodes along the successful path are listed in the third part of the output from the parse:

PATH: ("INITSTRING" QUEST WHQUEST WHNG QDET WHAT "NUM" ADJNOUN ADJSTRING "ADV" ADJ OADJ LITTLE ADJSTRING "ADV" ADJ OADJ BRASS "ADJSTRING" NOUN PARTS "ENDINGS" FULLFORM AUX BEAUX ARE "VG-MODIFIERS" WHSUBJ "THERE" COP PREPCOMPL IN ART THE "ORD" "NUM" "ADJSTRING" NOUN BOX "ENDINGS")

A more detailed listing of all the entries in the parse along the successful path is presented in Appendix C.

4. The Utterance the System Heard

The fourth part of the output from the parse contains the utterance identified as a result of the parsing:

SYSTEM HEARD: (WHAT LITTLE BRASS PARTS ARE IN THE BOX)

5. The Response of the System

The fifth part of the output from the parse shows the response of the system:

RESPONSE: 2 SCREWS

There were two little brass screws in the box at the time the question was asked.

6. The Parse Tree

The sixth part of the output from the parse contains a tree representation of the syntactic structure of the utterance:

```
PARSE TREE (CLAUSE MAJOR QUESTION BE WHQUEST)
   SUBJECT: FOCUSELT: (NGROUP WHNGSIMP WHNG QDET PLURAL)
      (WHNGSIMP WHNG QDET PLURAL)
         WHAT (QDET)
         LITTLE (ADJ)
         BRASS (ADJ)
         PARTS (PLURAL NOUN)
   MVB: ARE (BE PLURAL PRESENT TENSEDVERB)
   GOALPR: IN (PREP)
   COMPLEMENT: (NGROUP NGSIMP DEF ART SINGULAR)
      (NGSIMP DEF ART SINGULAR)
         THE (DEF ART)
         BOX (SINGULAR NOUN)
```

The utterance is a WH-question consisting of one major clause. Its subject, which is the focus-element (it would not be for utterances like 'What tool do you want?'), is a noun phrase consisting of a question determiner, two adjectives, and a noun. The main verb is the present plural form of 'be'. There is a goal preposition, followed by a simple noun phrase as complement.

7. The Starting and Ending Points

The seventh part of the output from the parse specifies, in 10-ms units, the beginning and ending points of the utterance in the acoustic data:

```
INPUT START = 8
INPUT END = 201
```

These values may be useful in interpreting the following sections.

8. Words Getting Non-Zero Scores in Acoustic Tests

The seventh part of the trace contains a list of the words that were identified as possibly present during the acoustic verification steps:

```
WORDS GETTING NONZERO VERIFICATION DURING PARSE
8    ARE .9 11 22
     HOW .5 11 22
     WHAT .9 11 26
22   THE 1.0 27 37
26   ONE 1.0 27 41
     HANDL 1.0 23 49 2
     LITTL 1.0 27 49
41   ARE 1.0 43 49
49   THE 1.0 50 63
     WRENC .56 58 81 2
     HANDL .5 50 87 2
     FAUCE .49248 50 81 2
     BOX 1.0 50 96 2
     BRASS 1.0 50 81
63   WRENC .56 60 81
     HANDL .40095 63 87
     BOX 1.0 50 96
81   WRENC .8 97 122 2
     PART 1.0 82 114 2
     FAUCE 1.0 91 150
87   PLZ .85 91 96 2
96   ARE 1.0 97 112
112  THE 1.0 124 131
114  PLS 1.0 116 122
122  ARE 1.0 126 137
137  THERE 1.0 137 148
     IN 1.0 132 145
145  THE 1.0 137 148
148  ON 1.0 157 178
     BOX 1.0 149 201
FOUND:30 TRIED:104 TIMES:141
```

On the first line, the number 8 indicates the location at which the word verification routines began to look for ARE. The value .9 is the result of the acoustic test; values can range from 0.0 to 1.0. The last two numbers are the beginning and ending points established for that word. An extra number at the end of some entries, for example, the 2 for HANDL, show the number of processes that called for that word at that location; of course, the verification test is only done once. PLZ is the voiced plural ending; PLS is the unvoiced plural ending; there also is a PLES for plural with inserted vowel.

This list makes it possible to trace both the correct path and the partial false paths in the parsing that resulted from failures of the word functions to reject words. For the correct path, beginning with WHAT, its end point directs one to words that begin at that location: ONE, HANDL, LITTLE. LITTLE leads to 49; BRASS to 81; PART to 114; PLS to 122; ARE to 137; IN to 145: THE to 148; BOX to 201; and 201 is the end

point of the utterance. The sequences ARE THE and HOW THE are not continued; no word is sought beginning at 37. WHAT LITTLE HANDLES ARE THE did not continue beyond 131. It should be noted that not all the sequences of words that can be constructed from the list are on the same path. It would be necessary to look at the complete trace for that information. Paxton (1974) presents all the false paths, and identifies the reasons for their failing.

The last line indicates that 30 words were found, that 104 words were tried, and that these 104 words were called for 141 times; as indicated above, the verification test is done only once for each word.

9. Words Getting Acoustic Tests

The last part of the trace lists all the words checked during the parse. Because of its length, the list is not reproduced here; it is included in Appendix B. The interpretation of the entries is the same as that given for the preceding section.

IV SYSTEM PERFORMANCE

A. General

The system has been in operation for only a few months. During this time, we have made many modifications to ensure that the various acoustic, syntactic, semantic, and pragmatic processing steps are working satisfactorily. Thus, although we have now processed 71 utterances, not all of them constitute "tests" of the system. That is, in developing the algorithms for a word function, the acoustic data for an utterance may have been used in establishing threshold values. Our experience with word functions is still sufficiently limited so that modifications do not necessarily generalize to accommodate the occurrence of a given word in a different context. In contrast, changes in the grammar and the semantics, which are made so that a particular utterance can be understood, contribute to the overall improvement of the system in a cumulative fashion. Before discussing the results for the total set of utterances, it is appropriate to consider the results for one block of ten that were processed as a test set.

B. Analysis of a Test Set of Utterances

Four sentences were recorded:

Z0 Put one washer in the faucet.
Z1 Grasp the crescent wrench.
Z2 Is it in it?
Z3 What little brass parts are in the box?

Three speakers were used: the two for whom thresholds in the word functions had been written (B and P), and one whose voice had not been recorded for the system before (K). Each speaker recorded the first three sentences; the fourth was recorded just by the third speaker, since the other two had recorded it previously.

The results for the test set were examined in a two-step procedure. First, the word functions were checked against the acoustic data for the utterances; these results are presented in Table 3. For three utterances (coincidentally, one for each speaker) all of the word functions worked correctly. For four others, adjustments in thresholds were made. For the last three, a change in one of the algorithms would have been required.

Table 3

ACOUSTIC RESULTS FOR THE TEST UTTERANCES:
WORD FUNCTIONS REQUIRING MODIFICATION

	Speaker B	Speaker P	Speaker K
Z0	put	put, one, faucet	washer, in
Z1	wrench*	OK	crescent, wrench
Z2	OK	in*	OK
Z3			little*, part
Subtotal	12/14 = 86%	10/14 = 71%	17/23 = 74%
Total		39/51 = 77%	

----
*Algorithm changes would have been required for these words; only threshold changes were made for the others.

Some examples will be given of the kinds of threshold adustments made. The values of the upper limit for the first formant for several of the vowels had to be changed. For 'put', the value had been set at 500, but in utterance Z0 for Speaker B, it was actually 518. Corresponding pairs of values for 'in' were 500 and 533, and for 'crescent' 600 and 602. For 'faucet', the upper limit on the variance about the line fitted to the second formant had been set at 5; in utterance Z0 for Speaker K, it was actually 5.9. Because of the relatively little experience we have had with setting thresholds for word functions, these adjustments are not considered to be significant errors in the system. Actually, a change in the form of the threshold cut-off function from absolute to graded would have accommodated most of the differences.

Changing an algorithm in a word function is more significant; it indicates a failure to account for a certain kind of acoustic event. For example, in utterance Z3 for Speaker K, the second liquid in 'little' had such a reduced flap-D that it could not be detected by our current algorithms. More adequate detectors would provide the discrimination needed. In compiling statistics for the acoustic section, these requirements for algorithmic changes are considered failures.

Given these interpretations, the acoustic results may be summarized as indicated at the bottom of Table 3. For the three speakers, the word functions were correct for 12/14 = 86%, 10/14 = 71%, and 17/23 = 74%, respectively; the aggregate value is 39/51 = 77%.

The seven utterances for which the word functions were considered to work satisfactorily were parsed. First, however, two minor changes were made. It was necessary to raise the priority for a construction with a null determiner (in Z0), because, through an oversight in setting the initial parameters, it had an unrealistically low value. The word 'is' was included among verbs that could take two anaphoric references; this modification had not been made when that addition to our anaphoric routines had been introduced for the other verbs. With these changes, five of the utterances were analyzed correctly, as shown in Table 4. For one, the system recognized 'a' rather than 'the'; the response from the system would be the same in either case. In the last utterance, the correct analysis was found, but the presence of vocal fry at the end of the utterance resulted in a lowering of the priority of that analysis; so, the parser continued to look for a longer word and, subsequently, accepted an interpretation for which the values of the word functions actually were lower.

Table 4

PARSING RESULTS FOR THE TEST UTTERANCES

	Speaker B	Speaker P	Speaker K
Z0	OK	'a'/'the'	OK
Z1	--*	OK	OK
Z2	OK	--*	failed
Z3			--*
Subtotal	2/2 = 100%	2/2 = 100%	2/3 = 67%
Total		6/7 = 86%	

----
*Parsing was not attempted for these utterances.

To summarize, the system parsed six of the seven utterances for a rating of 86%. If we include the three utterances that failed on acoustic grounds, the system analyzed six out of ten, or 60%.

The results from this set of test utterances represent our first attempt at an assessment of the system. They are more valuable to us as guides to further work, than as benchmarks of achievement. From this perspective, the implications of their analysis will be considered in the next section together with the results from all of the utterances that have been processed by the system.

C. Analysis of All Processed Utterances

Of the almost 300 utterances we have recorded relating specifically to the faucet world task domain (there were also a large number done for the "blocks world"), 71 have been run through the system.* For most of the remainder, there are not enough word functions written to handle the vocabulary. About three dozen for which there are word functions have not been run, either because they contain constructions that we have not yet included in the grammar, because our semantics cannot yet process them, or because they do not make sense. Utterances in this last category were recorded primarily to provide alternate acoustic contexts without concern for their syntactic or semantic adequacy. (The larger set of utterances for which we do not have enough word functions also contains instances of each of these three categories.) Eventually, we would want the system to respond to every input in some constructive manner, but we believe that efforts in that direction are best deferred until we do better on the utterances the system should be able to process.

Of the 71 utterances run, the system returned a complete parse with a response for 51. Of these, 44 were understood correctly. This number includes three instances in which 'a' was recognized instead of 'the'; one with 'the' for 'a'; one with 'in' for 'on'; and one with 'one' for 'the'. In all six cases, the response of the system was appropriate for the utterance as recorded.

The other seven utterances were processed incorrectly. For three, a path for the correct parse also was present, but audible sounds on the recording after the last word (e.g.,

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*Appendix D lists all the sentences recorded for the faucet world task domain. Appendix E lists the 71 utterances processed and identifies the result of each analysis.

vocal fry) caused the system to look for an alternative analysis that would be longer. The results were: 'Pick up a big wrench.' instead of 'Pick up a big one.'; 'How many big brass parts are the handle?' instead of 'How many big brass parts are there?' (clearly, the grammar should have precluded that result); 'Is there a wrench?' instead of 'Is it in it?' (the priorities for the correct path were higher, except for the penalty caused by the faulty identification at the end of the utterance). In another, the path for the correct parse was present and the acoustic score for the correct word was actually higher; however, the combination with the plural form was slightly lower: 'How many wrenches are in the box?' instead of 'How many washers are in the box?' Two others accepted incorrect words without ever considering looking for the correct ones: 'How many big tools are on it?' instead of 'How many big tools are there?'; 'Is there a little one in the faucet?' instead of 'Is there a little one in the box?' (the path leading to 'faucet' was so high that it compensated for a relatively low rating for the acoustic match). In the last utterance, a word function failed, and a word with a relatively low acoustic score was accepted: 'Is there a little handle in a box?' instead of 'Is there a little one in the box?'

Twenty utterances never parsed. For 11 of these, the word functions failed to identify words that were present; with one exception ('one'), these were function words ('a', 'the', 'in', 'there') and words with liquids (three instances of 'tool' and two of 'little'). A more refined acoustic analysis will help with liquids, but function words have long been recognized as problems for speech recognition and speech understanding, and they will continue to be. We believe that it may be possible to develop syntactic and semantic strategies that will compensate for this kind of acoustic failure to some extent.

Another six utterances terminated by exceeding the limit on the number of processes that could be created (set for 500); however, each contained a path representing a correct analysis of the utterance up to the point of termination. Most of these cases resulted from failures by the word functions to reject words that were not present--with a consequent proliferation of paths in the analysis. Although better word functions also would help here, other sources of knowledge could be used advantageously to lower the priority functions for paths that were inappropriate for semantic or pragmatic reasons.

One utterance failed by exceeding the limit because a word was erroneously accepted at the beginning of the utterance, and the parser never returned to consider alternative words for that place. Another utterance terminated by exceeding the

process limit because a large gap between successive words reduced the priority of the correct path; procedures for handling interword coarticulation--required in any case--should help. The last utterance failed because the initial priority for 'one' as a noun group was set too low; however, the word itself was accepted at the appropriate position as an ordinal.

Table 5 provides a summary. In processing 71 utterances, the system responded as follows: 44 (62%) understood correctly; 7 (10%) understood incorrectly; and 20 (28%) not understood. As indicated above, the interpretation of these results is not clear; not all of the analyses constitute valid tests. However, the system was designed to make use of many sources of knowledge in the analysis of an utterance. Since the current performance reflects the use of only primitive capabilities, these results could be interpreted as a lower bound on the power of the system.

More important for further system development, the analysis of each utterance provides guidance for modifications. In addition, we know how to refine and augment each of the system components to handle inadequacies we already recognize. Therefore, we believe that our experiences with the SRI speech understanding system will prove valuable in our further efforts toward satisfying the specifications for system performance described in the ARPA Study Group Report (Newell, et al., 1973), now in conjunction with the System Development Corporation, as indicated in Section V.

Table 5

RESULTS FOR UTTERANCES PROCESSED

Understood Correctly		44	62%
Understood Incorrectly		7	10%
Not Understood		20	28%
Words Missed	11		
Path Proliferation	6		
Words Not Rejected	1		
Gap Penalty	1		
Priority Value	1		
TOTAL		71	100%

V THE DEVELOPMENT OF A JOINT SRI-SDC SYSTEM

A. Introduction

In accordance with the recommendations resulting from the mid-course evaluation of the ARPA Speech Understanding Research Program, SRI has begun collaboration with the System Development Corporation on the design and implementation of a joint system. It will combine features and components of the previous two systems, building directly on the work of both contractors.* The task domain selected for the initial efforts involves data management; the initial data base will contain information about naval vessels of the United States, the Soviet Union, and the United Kingdom. Following demonstration of satisfactory progress on this task, a second domain will be identified, and subsequent work will continue on both tasks.

The responsibility for the development of the joint system is shared by SRI and SDC. However, SRI will concentrate primarily on syntax, semantics, pragmatics, discourse analysis, and prosodics, while SDC will be concerned primarily with signal processing, acoustics, phonetics, phonology, and system software and hardware support. The initial implementation of the system will be at SDC on the Raytheon 704 and IBM 370/145 computers. Accessibility of the system over the ARPA Computer Network to other participants in the ARPA program will be provided at the earliest possible time.

During the remainder of the current contract, efforts by both SRI and SDC toward the implementation of a joint system have the following major objectives:

(1) Developing an initial operating version of the five-year system; the SRI parser and grammar are being revised and integrated with the SDC acoustic-phonetic and phonological components.

(2) Testing the robustness of the acoustic-phonetic algorithms of the current SDC system with a larger vocabulary (300 words); the existing SDC predictive linguistic constraints components are being used for this purpose.

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*For descriptions of the current SDC system activities, see Ritea (1974), Barnett (1974a), Barnett (1974b), Kameny (1974), Weeks (1974), Molno (1974), and Gillmann (1974).

B. Current Activities

The following tasks are currently in progress; all of them will continue into the following contract period. Primary responsibility for each is indicated in parentheses?

(1) System Architecture. (SRI, SDC) The design concepts underlying the systems developed by SRI and SDC during the first two years of the ARPA Program are being reanalyzed, and a new system is being designed that will combine the procedures for syntactic, semantic, and pragmatic analysis of SRI with the procedures for acoustic, phonetic, and phonological analysis of SDC. The SDC control structure language is being extended to accommodate the new design, and software support programs are being modified accordingly.

(2) Protocol Experiments. (SRI) We are locating people who are thoroughly familiar with information retrieval operations on data of the type contained in the initial task domain. On the basis of interviews with them, a set of tasks will be identified and used in eliciting task-oriented dialogs. Early results will be used immediately to determine additions to the vocabulary and to the data base. Subsequent analyses will guide revisions to the grammar and the design of an effective discourse model.

(3) Acoustic-Phonetic Analysis. (SDC) The algorithms used to build the A-Matrix for an utterance are being refined and extended, and new procedures are being added to improve the accuracy of the classifications.

(4) Mapping Procedures. (SDC) The current lexical mapping procedure, with minor modifications, will be adequate for testing the vocabulary additions using the current SDC system. More substantial changes are being made for coordination with the SRI parser and grammar in the initial version of the joint system.

(5) Parsing. (SRI) The design of the SRI parser is being revised to accommodate the SDC procedures for acoustic-phonetic analysis and lexical mapping. Changes also may result from additions to the grammar. An initial version of the revised parser will be operating in the new system by September.

(6) Grammar. (SRI) A major reorganization of the SRI grammar is being made. The selection of rules for the initial revision will be guided by dialogs collected during the early protocol experiments. The structure of the grammar is being changed so that additions and modifications can be made more easily.

(7) Semantics. (SRI) Major changes in the semantics developed for the original SRI task domain will be made initially to accommodate the data management task. Subsequently, as the data base is extended in accord with the findings from the protocol experiments, additional modifications will be made.

(8) System Hardware. (SDC) Work is proceeding on the ARPANET interface for the SDC computer facility. As the special purpose signal processing and acoustic analysis computers are acquired, they will be interfaced into the system.

(9) Support Contractors. (SRI, SDC) A set of tasks is being defined that can guide the activities of other ARPA contractors so that they will begin to contribute directly to further system development.

(10) Management Review. (SRI, SDC) A joint SRI-SDC committee has been formed to monitor the progress of the overall effort. It will meet quarterly, and its deliberations will form the basis for the Quarterly Management Reports. In addition, technical developments will be reviewed monthly by the two Project Leaders.

REFERENCES

Baranofsky, Sharon. Semantic and Pragmatic Processing in the SRI Speech Understanding System. MS, Artificial Intelligence Center, Stanford Research Institute, Menlo Park, California, March 1974.

Barnett, Jeffrey A. A Phonological Rule Compiler. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University. Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 188-192. (A)

Barnett, Jeffrey A. Module Linkage and Communication in Large Systems. Invited Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. To be published by Academic Press, New York, 1974. (B)

Becker, Richard, and Poza, Fausto. Acoustic Processing in the SRI Speech Understanding System. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 188-192.

Deutsch, Barbara G. The Structure of Task-Oriented Dialogs. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 250-254.

Gillmann, Richard A. Automatic Recognition of Nasal Phonemes. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 74-79.

Kameny, Iris. Comparison of the Formant Spaces of Retroflexed and Non-Retroflexed Vowels. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 80-84.

Molho, Lee. Automatic Recognition of Fricatives and Plosives in Continuous Speech. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15-19 April 1974. IEEE, New York, 68-73.

Newell, Allen, et al. Speech Understanding Systems. North-Holland Publishing Company, Amsterdam, 1973.

Paxton, William H. A Best-First Parser. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 218-225.

Paxton, William H., and Robinson, Ann E. A Parser for a Speech Understanding System. Advance Papers, International Joint Conference on Artificial Intelligence, Stanford, California, 20-23 August 1973. Stanford Research Institute, Menlo Park, California, 1973, 216-222.

Reboh, Rene, and Sacerdoti, Earl. A Preliminary QLISP Manual. Technical Note 81, Artificial Intelligence Center, Stanford Research Institute, Menlo Park, California, August 1973.

Ritea, H. Barry. A Voice-Controlled Data Management System. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 28-31.

Robinson, Jane J. Performance Grammars. Invited Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. To be published by Academic Press, New York, 1974.

Walker, Donald E. Speech Understanding Research. Annual Report, Project 1526, Artificial Intelligence Center, Stanford Research Institute, Menlo Park, California, February 1973. (A)

Walker, Donald E. Speech Understanding Through Syntactic and Semantic Analysis. Advance Papers, International Joint Conference on Artificial Intelligence, Stanford, California, 20-23 August 1973. Stanford Research Institute, Menlo Park, California, 208-215. (B)

Walker, Donald E. Speech Understanding, Computational Linguistics, and Artificial Intelligence. In Computational and Mathematical Linguistics, Proceedings of the International Conference on Computational Linguistics, Volume I. Edited by Antonio Zampolli. Casa Editrice Leo S. Olschki, Firenze, 1973. (C)

Walker, Donald E. The SRI Speech Understanding System. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE New York, 1974, 32-37.

Weeks, Rollin V. Predictive Syllable Mapping in a Continuous Speech Understanding System. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 154-158.

Winograd, Terry. Procedures as Representation for Data in a Computer Program for Understanding Natural Language. Report MAC-TR-84, Project MAC, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1971. Published as Understanding Natural Language, Academic Press, New York, 1972.

APPENDIX A

The Result File from the Acoustic Preprocessing of the Utterance 'What Little Brass Parts Are in the Box?'

DIGITAL FILTER OUTPUT								LPC "FORMANT" PEAKS								LPC HALF-BANDWIDTH VALUES				
INT	CL	RAW	VOICE	LOW	MID	HIGH	INT	CL	F1	F2	F3	F4	F5	RMS	B1	B2	B3	B4	B5
1	SI	2.	-43.0	-50.0	-50.0	-50.0	-40.3	1	SI	117.	1131.	1969.	2613.	3432.	-18.0	0.0	0.0	0.0	0.0	0.0
2	SI	2.	-43.8	-42.4	-50.0	-50.0	-41.2	2	SI	975.	1833.	2769.	3588.	4446.	-17.7	0.0	0.0	0.0	0.0	0.0
3	SI	1.	-47.7	-41.2	-50.0	-50.0	-40.3	3	SI	1014.	1716.	2301.	3276.	4095.	-18.6	0.0	0.0	0.0	0.0	0.0
4	SI	3.	-41.7	-43.6	-50.0	-50.0	-39.6	4	SI	1014.	2067.	2652.	3315.	4212.	-17.4	0.0	0.0	0.0	0.0	0.0
5	SI	[illegible]	-47.1	-45.9	-50.0	-50.0	-41.0	5	SI	936.	1950.	3471.	4212.	5148.	-18.5	0.0	0.0	0.0	0.0	0.0
6	SI	2.	-44.6	-45.7	-50.0	-50.0	-40.7	6	SI	390.	1716.	2379.	3471.	4212.	-17.8	0.0	0.0	0.0	0.0	0.0
7	SI	3.	-42.[illegible]	-40.7	-50.0	-50.0	-39.8	7	SI	858.	1372.	3393.	4212.	4836.	-17.6	0.0	0.0	0.0	0.0	0.0
8	SI	5.	-37.0	-38.5	-50.0	-50.0	-40.4	8	SI	1131.	1911.	2964.	3471.	4329.	-18.5	0.0	0.0	0.0	0.0	0.0
9	SI	10.	-30.7	-30.0	-46.4	-50.0	-40.9	9	SI	234.	1092.	2028.	2847.	3588.	-17.7	0.0	0.0	0.0	0.0	0.0
10	VS	30.	-21.3	-21.6	-35.2	-44.3	-40.1	10	VS	273.	1872.	2691.	3822.	4173.	-14.8	153.2	272.3	213.9	255.0	282.8
11	V	150.	-7.3	-9.8	-15.5	-23.1	-37.3	11	V	351.	702.	1886.	4797.	5499.	-7.6	61.1	153.2	136.6	224.2	133.3
12	V	172.	-6.1	-5.7	-7.7	-14.1	-31.0	12	V	429.	780.	2847.	3276.	4485.	-6.7	93.7	123.3	54.6	87.1	234.4
13	V	214.	-4.2	-5.1	-4.7	-11.5	-21.3	13	V	429.	702.	2808.	3198.	4563.	-5.1	74.1	163.4	41.7	126.6	356.7
14	V	208.	-4.6	-5.3	-7.1	-11.4	-21.8	14	V	429.	819.	2808.	3198.	5577.	-5.5	100.2	186.6	64.3	133.3	328.3
15	V	263.	-2.4	-4.5	-4.6	-7.0	-16.6	15	V	507.	936.	2769.	3198.	3549.	-3.5	77.3	87.1	48.1	110.1	139.9
16	V	235.	-3.4	-3.7	-3.1	-5.5	-15.2	16	V	546.	1014.	2769.	3276.	3666.	-2.9	67.6	67.6	57.8	120.0	163.3
17	V	296.	-1.4	-3.1	-2.8	-3.4	-13.2	17	V	585.	1053.	2730.	3276.	3666.	-2.0	54.6	38.4	28.8	106.8	106.8
18	V	348.	0.0	-3.3	0.0	-1.4	-8.9	18	V	585.	1092.	2730.	3354.	3744.	-0.9	54.6	70.8	100.2	103.5	87.1
19	V	307.	-1.1	-4.2	-0.3	0.0	-11.3	19	V	585.	1170.	2769.	3432.	3822.	-1.0	38.4	35.2	113.4	97.0	110.1
20	V	286.	-1.7	-5.3	-2.6	-2.4	-7.3	20	V	585.	1209.	2223.	3081.	3627.	-1.5	67.6	19.2	244.7	54.6	83.9
21	V	163.	-5.8	-8.2	-5.3	-5.0	-11.5	21	V	546.	1209.	3003.	3861.	5772.	-3.0	77.3	19.2	44.9	123.3	227.6
22	V	108.	-10.2	-7.3	-17.6	-19.0	-26.4	22	V	312.	1131.	2964.	3978.	4680.	-9.6	83.9	44.9	64.3	170.0	210.5
23	VS	72.	-13.7	-11.5	-22.5	-29.3	-39.3	23	VS	234.	1209.	3003.	3900.	4797.	-11.8	44.9	100.2	106.8	103.5	262.0
24	V	102.	-10.7	-10.0	-18.5	-27.6	-27.3	24	V	273.	1170.	2106.	2925.	3822.	-9.9	22.4	106.8	54.6	173.3	193.6
25	VS	111.	-9.9	-7.8	-18.7	-27.0	-34.4	25	VS	312.	1092.	2028.	3042.	3705.	-9.6	25.6	28.8	170.0	234.4	103.5
26	VS	146.	-7.5	-7.2	-18.8	-26.3	-35.6	26	VS	312.	10[illegible].	2223.	2886.	3627.	-9.4	28.8	28.8	173.3	353.1	77.3
27	V	136.	-4.1	-5.5	-12.7	-23.8	-36.0	27	V	312.	1053.	2145.	3081.	3744.	-8.6	28.8	32.0	143.2	200.3	203.7
28	V	187.	-5.4	-4.1	-11.0	-21.6	-34.9	28	V	312.	1092.	2145.	3159.	3686.	-7.8	16.0	28.8	170.0	348.0	285.4
29	V	175.	-6.0	-3.1	-10.3	-22.5	-32.4	29	V	312.	1092.	2184.	2964.	3588.	-7.[illegible]	19.2	54.6	90.4	220.7	103.3
30	V	208.	-4.5	-2.6	-10.0	-21.4	-31.5	30	V	273.	1209.	2223.	3120.	3744.	-7.[illegible]	19.2	110.1	[illegible]0.6	170.0	156.6
31	V	179.	-5.8	-2.1	-10.0	-22.8	-28.2	31	V	312.	1248.	2028.	2925.	3744.	-7.7	25.6	103.5	44.9	180.1	139.9
32	V	223.	-3.9	-2.8	-9.7	-18.6	-22.1	32	V	351.	1287.	2847.	3549.	4251.	-8.0	35.2	83.9	64.3	106.8	303.7
33	V	215.	-4.2	-2.8	-5.8	-13.9	-20.2	33	V	429.	1326.	2847.	3471.	3624.	-5.1	51.3	57.5	51.1	159.9	126.6
34	V	343.	-0.1	-1.2	-3.7	-8.9	-13.5	34	V	429.	1287.	2847.	3432.	3705.	-3.3	30.4	57.8	57.8	163.3	81.1
35	V	325.	-0.6	-0.2	-1.1	-8.1	-13.5	35	V	429.	1326.	2808.	3393.	3705.	-3.1	35.2	83.9	25.6	183.4	48.1
36	V	345.	-0.1	0.0	-2.0	-7.5	-10.9	36	V	429.	1326.	2847.	3432.	3744.	-2.9	41.7	80.6	41.7	120.0	74.1
37	V	313.	-0.9	-0.6	-2.2	-8.5	-13.5	37	V	429.	1248.	2847.	3432.	3705.	-3.6	41.7	41.7	44.9	159.9	90.4
38	V	234.	-3.4	-1.6	-6.0	-12.0	-15.2	38	V	351.	1131.	2145.	2847.	3471.	-6.4	38.4	28.8	159.9	146.6	77.3
39	V	213.	-4.3	-3.1	-6.9	-16.5	-18.4	39	V	351.	1092.	2106.	29[illegible].	3510.	-5.8	32.0	41.7	193.6	163.3	51.3
40	V	251.	-2.9	-2.7	-5.7	-13.4	-16.0	40	V	390.	1092.	2184.	3003.	3588.	-5.1	48.1	54.6	356.7	234.4	57.8
41	V	260.	-2.5	-2.4	-4.5	-13.0	-20.5	41	V	390.	1170.	2730.	2964.	3744.	-4.7	51.3	106.8	129.9	67.6	84.3
42	V	279.	-1.9	-1.9	-3.5	-10.0	-19.3	42	V	390.	1131.	2808.	3003.	3471.	-3.4	44.9	77.3	61.1	77.3	139.9
43	V	276.	-2.0	-2.4	-3.8	-10.9	-17.8	43	V	429.	1131.	2847.	3081.	3471.	-3.8	54.6	70.8	57.8	100.2	116.7
44	V	297.	-1.4	-2.0	-2.8	-9.0	-14.0	44	V	429.	1131.	2847.	3120.	3510.	-3.8	[illegible]	93.7	54.6	110.1	163.3
45	V	277.	-2.[illegible]	-2.7	-3.4	-10.5	-17.6	45	V	429.	1131.	2847.	3120.	3549.	-4.0	[illegible]	110.1	70.8	110.1	173.3

INT	CL	RAW		VOICE	LOW	MID	HIGH
46	V	300.	-1.3	-2.3	-2.8	-9.0	-20.2
47	V	266.	-2.3	-3.0	-3.7	-11.3	-28.2
48	V	254.	-2.8	-2.2	-5.3	-12.3	-30.2
49	V	143.	-7.7	-4.4	-10.3	-19.9	-37.2
50	VS	153.	-7.2	-5.3	-17.6	-28.2	-39.0
51	VS	135.	-8.2	-5.1	-15.0	-27.2	-39.3
52	VS	119.	-9.4	-5.4	-16.5	-29.0	-39.7
53	VS	108.	-10.2	-7.2	-18.8	-30.4	-39.5
54	VS	65.	-14.5	-9.6	-22.4	-34.0	-40.0
55	VS	52.	-16.5	-11.3	-26.2	-37.4	-40.9
56	VS	49.	-17.0	-13.8	-28.6	-39.2	-39.9
57	VS	61.	-15.2	-13.0	-24.5	-25.9	-36.1
58	V	163.	-6.6	-8.0	-8.5	-13.5	-35.9
59	V	332.	-0.4	-3.9	-2.9	-7.2	-30.7
60	V	306.	-1.1	-2.1	-0.2	-4.4	-29.6
61	V	348.	-0.8	-2.3	-3.3	-5.7	-28.7
62	V	286.	-1.7	-1.9	-1.4	-3.4	-25.5
63	V	289.	-1.6	-2.5	-3.3	-3.5	-22.5
64	V	322.	-0.7	-2.7	-2.7	-3.2	-16.8
65	V	282.	-1.8	-2.3	-1.9	-2.3	-12.2
66	V	231.	-1.8	-2.7	-3.5	-3.9	-12.3
67	V	300.	-1.3	-2.9	-1.9	-2.7	-9.1
68	V	256.	-2.7	-3.2	-3.2	-3.2	-13.0
69	V	297.	-1.4	-3.6	-4.3	-4.6	-13.5
70	V	257.	-2.8	-3.4	-1.9	-2.9	-11.5
71	V	236.	-3.4	-3.9	-4.0	-4.6	-15.3
72	V	274.	-2.1	-4.2	-5.1	-5.8	-15.9
73	V	207.	-4.5	-3.3	-4.0	-4.7	-17.0
74	V	190.	-5.3	-3.5	-9.2	-11.5	-19.3
75	V	96.	-11.1	-5.0	-17.0	-19.5	-13.2
76	VH	43.	-18.1	-10.9	-27.3	-30.0	-5.8
77	S	57.	-15.7	-31.4	-39.1	-27.3	0.0
78	S	54.	-16.2	-34.0	-38.5	-24.2	-0.6
79	S	35.	-19.9	-33.8	-39.4	-26.1	-4.4
80	S	26.	-22.5	-31.4	-36.4	-26.1	-12.0
81	S	9.	-31.7	-28.1	-39.4	-34.5	-22.9
82	SI	6.	-35.5	-34.8	-50.0	-50.0	-38.4
83	SI	4.	-39.3	-33.3	-50.0	-50.0	-39.8
84	SI	4.	-38.8	-42.4	-50.0	-50.0	-41.6
85	SI	2.	-43.3	-35.5	-50.0	-50.0	-39.8
86	SI	2.	-44.2	-42.2	-50.0	-50.0	-39.5
87	SI	3.	-40.6	-42.7	-50.0	-50.0	-40.1
88	SI	1.	-50.0	-40.1	-50.0	-50.0	-41.1
89	T	6.	-34.9	-37.2	-37.4	-40.4	-33.8
90	T	14.	-27.9	-32.2	-31.0	-34.1	-35.8
91	VH	10.	-31.1	-26.0	-37.7	-34.6	-30.0
92	FT	13.	-28.5	-34.0	-29.7	-27.6	-25.0
93	FT	24.	-23.1	-35.1	-26.9	-21.6	[illegible]
94	FT	19.	-25.1	-34.3	-28.4	-24.4	-15.9
95	FT	14.	-27.6	-25.4	-30.1	-26.7	-25.5
96	FT	19.	-25.0	-28.0	-33.2	-29.6	-29.5

INT	CL	F1	F2	F3	F4	F5	RMS	B1	B2	B3	B4	B5
46	V	429.	1092.	2769.	3003.	3510.	-4.0	44.9	106.6	100.2	106.8	197.0
47	V	429.	1053.	2925.	3627.	4875.	-5.0	41.7	100.2	97.0	272.3	589.3
48	V	390.	1053.	2262.	2925.	4797.	-5.9	41.7	120.0	193.6	64.3	200.3
49	V	351.	1131.	2223.	3003.	4329.	-9.4	61.1	93.7	159.9	64.3	156.6
50	VS	273.	1014.	2028.	3159.	3588.	-9.6	38.6	255.0	183.4	310.7	251.6
51	VS	273.	697.	2067.	2964.	3588.	-9.4	28.8	176.7	190.2	113.4	120.0
52	VS	273.	936.	1969.	2925.	3744.	-10.5	32.0	217.3	237.9	183.4	200.3
53	VS	273.	1950.	3003.	3705.	4524.	-11.4	35.2	139.9	262.0	170.0	258.5
54	VS	273.	1833.	3198.	3939.	4680.	-12.6	36.4	255.0	159.9	335.4	176.7
55	VS	273.	2886.	3744.	4719.	5733.	-14.1	48.1	296.7	248.2	237.9	258.5
56	VS	273.	2145.	2925.	3783.	4524.	-14.3	51.3	133.3	241.3	231.0	147.9
57	VS	312.	1014.	1716.	2847.	3510.	-12.3	110.1	133.3	103.5	149.9	345.3
58	V	468.	1092.	1755.	2886.	4524.	-5.5	57.8	67.6	36.4	25.6	396.1
59	V	468.	1131.	1716.	2847.	4134.	-2.9	38.4	44.9	35.2	41.7	231.0
60	V	468.	1170.	1755.	2808.	3315.	-2.3	44.9	32.0	28.8	28.8	227.6
61	V	468.	1248.	1911.	2847.	5421.	-2.6	80.6	57.6	57.8	70.8	353.1
62	V	546.	1287.	1969.	3003.	5070.	-1.7	100.2	35.2	35.2	237.9	444.1
63	V	585.	1326.	2067.	3042.	4992.	-1.8	70.8	41.7	67.6	70.8	317.7
64	V	585.	1365.	2106.	3061.	3510.	-1.7	70.8	54.6	77.3	90.4	44.9
65	V	585.	1404.	2164.	3198.	3549.	-1.4	61.1	35.2	83.9	217.3	44.9
66	V	585.	1443.	2223.	3237.	3588.	-2.0	67.6	51.3	70.8	173.3	70.8
67	V	546.	1443.	2164.	3354.	3627.	-1.5	74.1	41.7	67.6	170.0	77.3
68	V	585.	1482.	2223.	3471.	3705.	-2.1	67.6	38.4	67.6	183.4	139.9
69	V	585.	1482.	2223.	3432.	3783.	-2.4	77.3	54.6	173.3	156.6	90.4
70	V	585.	1443.	2223.	2847.	3432.	-2.3	90.4	44.9	200.3	170.0	83.9
71	V	585.	1404.	2262.	2769.	3510.	-3.1	48.1	61.1	399.7	120.0	100.2
72	V	546.	1365.	2769.	3510.	3900.	-3.6	67.6	70.8	93.7	149.9	166.6
73	V	507.	1365.	2691.	3744.	5967.	-4.1	83.9	51.3	110.1	279.3	48.1
74	V	507.	1326.	2730.	3783.	5928.	-6.1	116.7	32.0	51.3	143.2	180.1
75	V	351.	1638.	2691.	3588.	4251.	-6.0	163.3	139.9	61.1	133.3	57.6
76	VH	1404.	2847.	3549.	4212.	4836.	-2.3	376.1	170.0	170.0	100.2	129.9
77	S	1326.	3432.	4056.	4563.	5382.	0.0	417.8	1195.0	51.3	248.2	289.7
78	S	1092.	1989.	2886.	3471.	3783.	-0.8	80.6	207.1	190.2	110.1	57.8
79	S	1131.	2691.	3276.	3744.	4563.	-3.6	722.2	2081.5	93.[illegible]	170.0	251.8
80	S	936.	3081.	4797.	5694.	6747.	-5.9	110.1	110.1	244.7	303.7	265.4
81	S	1248.	2262.	3120.	3822.	4953.	-15.2	156.6	100.2	100.2	186.8	293.2
82	SI	1248.	2028.	2847.	3393.	4056.	-17.7	0.0	0.0	0.0	0.0	0.0
83	SI	1248.	21[illegible].	2964.	3744.	4602.	-18.9	0.0	0.0	0.0	0.0	0.0
84	SI	1287.	2223.	3003.	4056.	5265.	-18.2	0.0	0.0	0.0	0.0	0.0
85	SI	1053.	1755.	2886.	3705.	4485.	-17.6	0.0	0.0	0.0	0.0	0.0
86	SI	195.	1365.	1911.	3510.	4446.	-17.8	0.0	0.0	0.0	0.0	0.0
87	SI	1209.	2106.	2925.	3432.	4212.	-17.8	0.0	0.0	0.0	0.0	0.0
88	SI	1014.	2067.	3003.	4056.	4797.	-18.6	0.0	0.0	0.0	0.0	0.0
89	T	468.	1443.	1989.	3081.	4366.	-15.0	74.1	207.1	314.2	210.5	193.6
90	T	429.	1365.	2106.	3237.	4329.	-15.4	146.6	153.2	231.0	123.3	193.6
91	VH	741.	1326.	2379.	3198.	3705.	-13.4	80.6	156.6	129.9	70.8	300.2
92	FT	741.	1209.	2262.	2847.	3198.	-10.0	87.1	64.3	63.9	170.0	61.1
93	FT	819.	1170.	2223.	3198.	3978.	-7.6	149.9	36.4	234.4	16.0	248.2
94	FT	663.	1131.	2262.	2925.	3237.	-9.2	87.1	35.2	44.9	166.8	97.0
95	FT	663.	1092.	2301.	3159.	4407.	-11.3	183.4	41.7	54.6	87.1	346.0
96	FT	1131.	2223.	3120.	4095.	5265.	-12.8	116.7	77.3	70.8	237.9	190.2

INT	CL	RAW		VOICE	LOW	MID	HIGH
97	V	167.	-6.4	-12.1	-12.5	-11.6	-30.1
98	V	251.	-2.8	-3.5	-2.7	-3.4	-19.9
99	V	315.	-0.9	-2.8	-4.1	-4.4	-17.6
100	V	277.	-2.0	-2.4	-1.1	-1.6	-16.1
101	V	280.	-1.9	-3.4	-2.9	-2.2	-14.9
102	V	303.	-1.2	-4.8	-3.0	-2.2	-16.9
103	V	255.	-2.7	-4.7	-2.3	-1.7	-15.2
104	V	241.	-3.2	-5.9	-4.1	-3.0	-16.6
105	V	229.	-3.6	-6.5	-4.5	-4.1	-21.8
106	V	257.	-2.6	-7.3	-5.2	-3.5	-25.5
107	V	218.	-4.1	-6.4	-3.4	-4.6	-26.5
108	V	184.	-5.6	-7.3	-5.9	-7.3	-26.1
109	V	170.	-6.2	-6.5	-7.4	-11.2	-26.9
110	V	140.	-7.9	-7.5	-10.4	-15.9	-31.9
111	V	71.	-13.8	-10.3	-18.8	-25.9	-28.0
112	V	44.	-17.9	-13.7	-22.9	-32.7	-28.0
113	VH	8.	-32.9	-21.4	-33.6	-44.9	-30.6
114	SI	10.	-31.2	-31.6	-43.7	-50.0	-35.6
115	S	11.	-29.8	-30.1	-50.0	-46.2	-22.7
116	S	18.	-25.6	-29.0	-50.0	-34.8	-11.4
117	S	26.	-22.5	-31.9	-41.3	-31.3	-7.2
118	S	37.	-19.4	-29.6	-40.3	-25.0	-4.8
119	S	35.	-20.0	-35.7	-42.4	-26.2	-5.3
120	S	24.	-25.1	-35.7	-42.1	-27.7	-8.3
121	S	15.	-27.1	-37.1	-43.2	-30.0	-12.7
122	S	7.	-34.2	-43.4	-43.6	-36.7	-28.5
123	T	8.	-32.9	-32.6	-45.8	-39.5	-38.7
124	VS	28.	-22.0	-22.7	-38.2	-40.6	-40.5
125	VS	115.	-9.6	-9.9	-19.6	-25.6	-40.0
126	V	215.	-4.2	-4.2	-7.7	-13.4	-33.8
127	V	205.	-4.6	-4.7	-7.3	-12.5	-32.5
128	V	169.	-6.3	-6.1	-7.4	-14.8	-34.3
129	V	175.	-6.0	-5.2	-8.9	-15.7	-34.9
130	V	179.	-5.8	-6.1	-9.6	-16.1	-35.3
131	V	206.	-4.6	-5.7	-9.5	-15.2	-31.8
132	V	171.	-6.2	-4.6	-8.6	-15.7	-29.1
133	V	175.	-6.0	-5.0	-9.2	-17.2	-26.1
134	V	183.	-5.6	-4.8	-9.4	-17.3	-18.8
135	V	186.	-5.5	-5.6	-9.6	-17.3	-18.3
136		212.	-4.3	-4.6	-8.8	-15.7	-25.6
137	V	174.	-6.0	-4.8	-9.2	-18.5	-31.2
138	V	168.	-6.4	-4.6	-10.5	-21.2	-36.7
139	V	221.	-3.9	-4.5	-10.6	-20.7	-34.8
140	V	220.	-4.0	-5.3	-11.9	-20.4	-34.6
141	V	214.	-4.2	-4.6	-11.0	-20.0	-33.5
142	V	194.	-5.1	-4.9	-10.6	-20.9	-34.4
143	V	169.	-5.3	-4.8	-11.0	-21.3	-34.4
144	V	186.	-5.4	-6.1	-11.4	-21.3	-35.4
145	V	189.	-5.3	-6.3	-12.1	-20.2	-34.3
146	V	156.	-7.0	-6.3	-10.3	-16.7	-24.8
147	V	154.	-7.1	-6.2	-9.6	-17.1	-29.0

INT	CL	F1	F2	F3	F4	F5	RMS	B1	B2	B3	B4	B5
97	V	585.	1053.	2145.	3081.	4485.	-4.0	97.0	44.9	57.8	90.4	428.7
98	V	585.	1092.	2145.	3120.	3237.	-2.4	74.1	38.4	48.1	74.1	106.8
99	V	585.	1131.	2106.	3159.	4563.	-2.5	116.7	83.9	64.3	176.7	203.7
100	V	624.	1131.	2067.	3159.	3315.	-1.5	87.4	41.7	38.4	64.3	106.8
101	V	585.	1131.	2028.	3237.	5187.	-1.3	80.6	32.0	32.0	113.4	200.3
102	V	585.	1170.	1950.	3120.	4212.	-1.8	103.5	41.7	28.8	93.7	406.9
103	V	585.	1170.	1911.	3081.	3276.	-1.2	67.6	28.8	41.7	74.1	83.9
104	V	585.	1170.	1872.	3081.	4485.	-1.5	57.8	28.8	25.6	106.8	321.3
105	V	585.	1209.	1833.	3081.	4329.	-2.3	77.3	35.2	19.2	38.4	282.5
106	V	546.	1248.	1833.	3081.	4095.	-2.4	100.2	48.1	19.2	67.6	220.7
107	V	507.	1287.	1833.	2964.	3510.	-2.6	67.6	74.1	44.9	61.1	120.0
108	V	507.	1326.	1794.	2925.	3393.	-3.4	70.8	61.1	38.4	61.1	35.2
109	V	468.	1326.	1794.	2847.	3198.	-5.2	48.1	38.4	41.7	48.1	57.8
110	V	390.	1404.	2808.	3120.	3939.	-7.8	28.8	80.6	67.6	180.1	275.8
111	V	351.	1404.	2769.	3198.	3627.	-12.3	61.1	38.4	70.8	103.5	207.1
112	V	312.	1248.	1989.	2846.	3900.	-12.5	25.6	113.4	173.3	227.6	153.
113	VH	312.	1560.	2301.	3159.	3939.	-17.2	32.0	149.9	210.5	335.4	103.5
114	SI	1677.	2574.	3822.	4407.	5382.	-18.1	0.0	0.0	0.0	0.0	0.0
115	S	1170.	2145.	2964.	3588.	4017.	-10.4	346.0	197.0	123.3	163.3	74.1
116	S	1092.	2340.	3042.	3627.	3978.	-5.2	180.1	146.6	83.9	61.1	97.0
117	S	858.	1638.	3042.	3393.	3939.	-4.1	392.5	396.1	136.6	103.4	67.6
118	S	1092.	2340.	3159.	3510.	5070.	-2.9	156.6	5000.0	83.9	93.7	231.0
119	S	1560.	2652.	3432.	3783.	4680.	-2.9	241.3	100.2	57.8	200.3	146.6
120	S	780.	1482.	2535.	3159.	3354.	-6.0	356.7	237.9	146.6	159.9	136.6
121	S	624.	1326.	2457.	3081.	3861.	-8.7	146.6	156.6	126.6	70.8	321.3
122	S	429.	1443.	2340.	3042.	3705.	-12.3	498.6	[illegible]	93.7	32.0	231.0
123	T	1365.	2262.	2964.	4368.	5070.	-16.6	116.7	[illegible]	103.5	200.3	156.6
124	VS	234.	1404.	2184.	2964.	3939.	-15.3	126.6	149.9	159.9	217.3	446.9
125	VS	351.	1326.	1677.	2886.	4797.	-8.2	93.7	90.4	210.5	129.9	374.5
126	V	390.	1326.	1794.	2886.	4329.	-5.8	64.3	70.8	70.8	64.3	360.2
127	V	390.	1287.	1794.	2886.	5226.	-5.6	51.3	61.1	74.1	64.3	287.7
128	V	390.	1287.	1672.	2847.	3237.	-6.0	54.6	54.6	54.6	32.0	159.9
129	V	390.	1326.	1672.	2847.	4407.	-6.7	57.8	67.6	44.9	38.4	282.4
130	V	351.	1365.	1950.	2886.	4836.	-7.0	70.8	77.3	74.1	83.9	378.1
131	V	390.	1443.	2067.	2886.	4563.	-6.5	80.6	83.9	100.2	93.7	581.6
132	V	390.	1521.	2184.	2886.	3237.	-6.0	70.8	90.4	113.4	64.3	126.
133	V	390.	1560.	2301.	2964.	3198.	-6.3	77.3	103.5	110.1	67.6	80.
134	V	351.	1716.	2496.	3081.	3354.	-6.8	61.1	97.0	200.3	129.9	100.2
135	V	351.	1755.	2691.	3315.	3588.	-7.1	80.6	93.7	146.6	217.3	234.4
136	V	390.	1755.	2769.	3315.	4017.	-6.7	83.9	156.6	193.6	123.6	244.7
137	V	351.	1755.	2769.	3276.	4212.	-7.1	57.8	173.3	472.7	166.6	153.2
138	V	312.	897.	1989.	2691.	3432.	-7.6	32.0	207.1	173.3	90.4	159.9
139	V	312.	858.	2067.	2652.	3315.	-7.2	35.2	237.9	220.7	64.3	149.9
140	V	312.	858.	1989.	2652.	3276.	-7.2	51.3	258.5	113.4	74.1	129.9
141	V	312.	858.	2067.	2652.	3276.	-6.9	48.1	234.4	470.0	83.9	136.6
142	V	312.	2067.	2730.	3354.	4407.	-7.0	35.2	153.2	87.1	90.4	209.7
143	V	312.	2028.	2652.	3354.	4212.	-7.6	32.0	120.6	48.1	116.7	227.6
144	V	312.	1989.	2691.	3432.	4173.	-8.0	44.9	224.2	100.2	209.7	272.3
145	V	351.	1326.	2652.	3315.	3939.	-7.9	48.1	90.4	234.4	220.7	87.1
146	V	429.	1443.	2691.	3276.	3822.	-6.6	77.3	97.0	74.1	97.0	97.0
147	V	390.	1365.	2535.	3120.	3666.	-7.1	51.3	74.1	193.6	207.1	136.6

INT	CL	RAW		VOICE	LOW	MID	HIGH
148	V	146.	-7.5	-6.3	-10.1	-18.8	-31.0
149	VS	116.	-9.6	-8.2	-15.2	-26.6	-38.5
150	VS	112.	-9.8	-8.1	-16.6	-27.1	-40.1
151	VS	112.	-9.8	-9.5	-18.3	-28.0	-38.4
152	VS	80.	-12.8	-10.6	-19.6	-30.0	-39.3
153	VS	69.	-14.0	-11.8	-20.8	-31.8	-40.1
154	VS	60.	-15.3	-11.3	-22.6	-33.6	-40.1
155	VS	59.	-15.4	-12.5	-24.7	-35.0	-39.7
156	VS	57.	-15.8	-13.3	-25.7	-35.7	-41.2
157	V	116.	-9.5	-12.8	-15.1	-18.4	-30.1
158	V	180.	-5.7	-8.2	-5.6	-7.6	-21.0
159	V	201.	-4.8	-5.9	-5.1	-5.4	-17.2
160	V	198.	-4.9	-6.8	-5.9	-5.8	-16.2
161	V	230.	-3.6	-7.5	-5.2	-4.6	-16.1
162	V	201.	-4.8	-7.0	-4.0	-3.9	-15.5
163	V	200.	-4.8	-8.4	-4.8	-3.5	-16.4
164	V	191.	-5.2	-7.8	-5.7	-4.6	-17.7
165	V	179.	-5.8	-9.1	-6.4	-5.5	-19.6
166	V	177.	-5.9	-9.7	-6.9	-6.2	-19.6
167	V	159.	-6.8	-9.8	-7.0	-7.3	-19.0
168	V	131.	-8.5	-9.7	-8.3	-8.1	-20.0
169	V	124.	-8.9	-10.5	-10.3	-9.6	-22.3
170	V	111.	-10.0	-11.0	-10.7	-9.7	-21.9
171	V	106.	-10.3	-10.6	-11.3	-10.4	-21.6
172	V	107.	-10.3	-11.7	-11.6	-10.5	-24.9
173	V	98.	-11.0	-12.4	-12.6	-11.0	-17.9
174	V	76.	-13.3	-12.6	-16.3	-15.6	-21.6
175	V	52.	-16.5	-12.3	-20.7	-19.3	-31.4
176	VS	34.	-20.3	-14.4	-30.2	-29.5	-36.1
177	VS	29.	-21.7	-15.8	-39.0	-36.2	-39.2
178	VS	11.	-30.1	-19.7	-45.3	-43.3	-39.2
179	SI	1.	-47.5	-28.3	-50.0	-48.5	-40.1
180	SI	3.	-41.2	-46.5	-50.0	-50.0	-40.7
181	SI	4.	-39.1	-37.8	-50.0	-50.0	-40.0
182	SI	2.	-45.2	-40.5	-50.0	-50.0	-41.1
183	SI	2.	-46.2	-46.0	-50.0	-50.0	-40.8
184	SI	3.	-42.5	-42.0	-50.0	-50.0	-40.6
185	SI	1.	-47.9	-48.0	-50.0	-50.0	-40.5
186	SI	2.	-43.8	-49.4	-50.0	-50.0	-39.0
187	FT	15.	-27.3	-47.0	-31.8	-25.7	-26.6
188	FT	12.	-29.0	-32.6	-35.7	-35.1	-22.0
189	FT	11.	-29.9	-33.9	-48.6	-34.8	-16.4
190	FT	9.	-31.9	-38.5	-49.0	-39.4	-16.4
191	FT	11.	-29.9	-41.9	-50.0	-39.0	-14.2
192	FT	16.	-26.7	-44.2	-50.0	-36.3	-10.6
193	FT	11.	-29.8	-45.7	-50.0	-38.5	-14.0
194	FT	11.	-30.4	-43.6	-50.	-38.8	-14.5
195	FT	11.	-30.3	-47.1	-50.0	-37.7	-14.1
196	FT	6.	-36.0	-50.0	-50.0	-40.9	-21.9
197	FT	5.	-37.1	-49.0	-50.0	-42.4	-22.6
198	FT	6.	-35.3	-49.4	-48.[illegible]	-40.0	-20.6

INT	CL	F1	F2	F3	F4	F5	RMS	B1	B2	B3	B4	B5
148	V	390.	1248.	2262.	3276.	4485.	-8.4	36.4	41.7	310.7	176.6	208.9
149	VS	312.	1170.	2340.	3471.	4368.	-10.6	28.6	100.2	220.7	227.6	248.2
150	VS	312.	1209.	2184.	2730.	3471.	-10.7	32.0	139.9	244.7	314.2	139.9
151	VS	312.	1248.	2301.	3159.	3939.	-11.2	44.9	159.9	139.9	166.6	217.3
152	VS	312.	1170.	2379.	3237.	4095.	-11.6	51.3	156.6	133.6	70.8	120.0
153	VS	312.	1170.	2379.	3159.	5148.	-12.1	41.7	103.5	331.8	234.4	183.4
154	VS	312.	1131.	2262.	3237.	4290.	-12.9	38.4	123.3	103.5	200.3	279.3
155	VS	273.	1131.	2223.	3003.	3588.	-13.8	35.2	133.3	129.9	213.9	227.6
156	VS	273.	1131.	1950.	2847.	3276.	-14.0	41.7	241.3	210.5	146.6	202.8
157	V	468.	1092.	2496.	2925.	3432.	-7.1	61.1	156.6	203.7	307.2	106.8
158	V	585.	1053.	2613.	3198.	3549.	-4.0	57.8	48.1	153.2	110.1	113.4
159	V	624.	1053.	2652.	3198.	3510.	-3.3	44.9	32.0	116.7	116.7	77.3
160	V	663.	1092.	2691.	3198.	3549.	-3.7	64.3	38.4	123.3	133.3	93.7
161	V	624.	1092.	2730.	3198.	3588.	-3.2	51.3	35.2	97.0	103.5	110.1
162	V	663.	1092.	2730.	3198.	3627.	-2.4	54.6	32.0	70.8	87.1	67.6
163	V	663.	1092.	2730.	3198.	3627.	-2.1	54.6	25.6	67.6	93.7	87.1
164	V	663.	1092.	2730.	3237.	3666.	-2.7	54.6	25.6	64.3	100.2	100.2
165	V	663.	1092.	2730.	3198.	3744.	-3.7	70.8	32.0	70.8	110.1	90.4
166	V	663.	1092.	2691.	3237.	3627.	-4.5	103.5	51.3	77.3	149.9	143.2
167	V	663.	1092.	2730.	3237.	3666.	-4.7	110.1	83.9	116.7	163.3	146.6
168	V	663.	1131.	2730.	3627.	4953.	-4.6	80.6	48.1	159.9	159.9	265.4
169	V	663.	1131.	2730.	3315.	6201.	-4.8	77.3	44.9	186.8	251.6	139.9
170	V	663.	1131.	2652.	3549.	5187.	-4.6	97.0	28.6	139.9	176.7	300.2
171	V	702.	1131.	2691.	3237.	3627.	-5.3	74.1	25.6	126.6	156.6	74.1
172	V	702.	1131.	2574.	3315.	3627.	-6.0	90.4	32.0	143.2	244.7	106.8
173	V	702.	1131.	2535.	3627.	5070.	-6.5	139.9	35.2	183.4	54.6	279.3
174	V	702.	1131.	2613.	3627.	4953.	-9.4	116.7	25.6	213.9	77.3	353.1
175	V	312.	858.	1131.	2340.	3705.	-10.6	300.2	265.4	35.2	126.6	129.9
176	VS	1209.	2145.	2925.	3783.	4758.	-15.0	22.4	436.0	193.6	176.7	166.6
177	VS	1248.	2613.	3549.	4992.	6045.	-15.8	44.9	227.6	143.7	176.7	265.4
178	VS	1209.	1911.	2769.	3744.	4446.	-17.7	67.6	282.8	353.1	146.6	183.4
179	SI	546.	1248.	2106.	2769.	3666.	-18.5	0.0	0.0	0.0	0.0	0.0
180	SI	1287.	2418.	3627.	4758.	5889.	-18.4	0.0	0.0	0.0	0.0	0.0
181	SI	1404.	2691.	4290.	5265.	6006.	-17.9	0.0	0.0	0.0	0.0	0.0
182	SI	1287.	2184.	3042.	3588.	4446.	-18.7	0.0	0.0	0.0	0.0	0.0
183	SI	1014.	2340.	3198.	3978.	4680.	-18.4	0.0	0.0	0.0	0.0	0.0
184	SI	663.	1794.	2964.	4017.	4602.	-17.7	0.0	0.0	0.0	0.0	0.0
185	SI	663.	2028.	2457.	3510.	4368.	-18.5	0.0	0.0	0.0	0.0	0.0
186	SI	1170.	2145.	3198.	3939.	4758.	-17.5	0.0	0.0	0.0	0.0	0.0
187	FT	741.	1287.	3198.	3861.	4290.	-11.3	293.2	110.1	428.7	241.3	248.2
188	FT	1365.	1872.	3276.	3939.	4446.	-10.2	156.6	210.5	279.3	70.8	163.3
189	FT	1404.	1794.	3159.	3822.	4758.	-8.8	90.4	163.3	241.3	106.8	183.4
190	FT	507.	1365.	2223.	3003.	3705.	-9.9	300.2	48.1	156.6	265.4	113.4
191	FT	351.	1365.	2223.	3159.	3939.	-7.4	480.1	113.4	149.9	113.4	38.4
192	FT	390.	1482.	3120.	3861.	4680.	-7.2	450.6	120.0	113.4	183.4	93.7
193	FT	1443.	2223.	3042.	3822.	4680.	-7.6	139.9	517.3	321.3	22.4	159.9
194	FT	663.	1404.	2964.	3783.	452[illegible].	-7.9	349.6	186.8	100.2	120.0	296.7
195	FT	624.	1950.	3081.	3666.	4680.	-9.6	300.2	224.2	87.1	61.1	133.3
196	FT	624.	1482.	2145.	3081.	3666.	-11.4	268.9	123.3	186.8	83.9	93.7
197	FT	1638.	3003.	3510.	3861.	4641.	-12.4	106.8	248.2	87.1	241.3	224.2
198	FT	585.	1404.	2223.	3003.	3549.	-11.2	143.2	44.9	139.9	146.6	61.1

INT	CL	RAW	VOICE	LOW	MID	HIGH
199	FT	6. -35.2	-43.1	-42.7	-39.7	-22.4
200	FT	6. -34.6	-44.3	-45.4	-39.5	-40.9
201	FT	5. -37.4	-47.7	-50.0	-41.4	-26.4
202	SI	2. -45.8	-41.4	-50.0	-49.6	-36.4
203	SI	1. -48.8	-49.1	-50.0	-50.0	-41.5
204	SI	3. -42.0	-43.3	-50.0	-50.0	-40.2
205	SI	2. -44.9	-42.2	-50.0	-50.0	-40.4
206	SI	1. -47.4	-43.9	-50.0	-50.0	-39.4
207	SI	1. -47.8	-44.5	-50.0	-50.0	-39.8
208	SI	2. -45.8	-45.0	-50.0	-50.0	-41.8
209	SI	1. -49.8	-45.9	-50.0	-50.0	-40.4
210	SI	2. -45.1	-50.0	-50.0	-50.0	-40.3
211	SI	2. -43.8	-48.9	-50.0	-50.0	-42.0
212	SI	1. -49.8	-50.0	-50.0	-50.0	-39.9
213	SI	2. -44.4	-50.0	-50.0	-50.0	-40.1
214	SI	3. -42.9	-45.7	-50.0	-50.0	-39.3
215	SI	2. -45.1	-50.0	-50.0	-50.0	-41.4
216	SI	2. -43.1	-45.0	-50.0	-50.0	-42.5
217	SI	2. -44.0	-48.3	-50.0	-50.0	-40.7
218	SI	2. -45.9	-47.8	-50.0	-50.0	-39.2
219	SI	3. -41.9	-46.1	-50.0	-50.0	-40.3
220	SI	2. -44.2	-47.4	-50.0	-50.0	-40.6
221	SI	2. -47.3	-49.7	-50.0	-50.0	-40.4
222	SI	1. -49.0	-46.0	-50.0	-50.0	-39.8
223	SI	1. -48.1	-50.0	-50.0	-50.0	-39.1
224	SI	2. -44.1	-50.0	-50.0	-50.0	-40.0
225	SI	3. -42.0	-46.5	-50.0	-50.0	-40.1
226	SI	3. -41.4	-47.1	-50.0	-50.0	-39.8
227	SI	1. -47.9	-46.1	-50.0	-50.0	-39.9
228	SI	2. -44.0	-47.1	-50.0	-50.0	-39.4
229	SI	2. -46.0	-45.0	-50.0	-50.0	-39.6
230	SI	3. -41.3	-43.1	-50.0	-50.0	-39.0

INT	CL	F1	F2	F3	F4	F5	RMS	B1	B2	B3	B4	B5
199	FT	546.	1365.	1950.	3003.	3432.	-11.8	170.0	159.9	220.7	106.0	67.6
200	FT	624.	1209.	3081.	3354.	40_7.	-12.0	286.2	314.2	116.7	97.0	163.3
201	FT	1209.	1794.	2925.	3198.	3861.	-15.3	272.3	213.[illegible]	166.6	44.9	203.7
202	SI	1014.	1716.	2613.	3159.	3900.	-18.3	0.0	0.0	0.0	0.0	0.0
203	SI	1014.	1794.	2769.	3783.	4485.	-18.3	0.0	0.0	0.0	0.0	0.0
204	SI	1326.	1911.	2574.	3471.	4251.	-17.3	0.0	0.0	0.0	0.0	0.0
205	SI	1326.	2691.	4173.	4036.	5772.	-18.0	0.0	0.0	0.0	0.0	0.0
206	SI	585.	1326.	2106.	2925.	3627.	-18.1	0.0	0.0	0.0	0.0	0.0
207	SI	1053.	1911.	2457.	3237.	3939.	-17.8	0.0	0.0	0.0	0.0	0.0
208	SI	936.	1833.	2535.	3510.	4173.	-18.9	0.0	0.0	0.0	0.0	0.0
209	SI	819.	1521.	2379.	3588.	4563.	-17.9	0.0	0.0	0.0	0.0	0.0
210	SI	312.	1287.	2223.	3510.	4290.	-17.9	0.0	0.0	0.0	0.0	0.0
211	SI	975.	1833.	2730.	3588.	4407.	-17.9	0.0	0.0	0.0	0.0	0.0
212	SI	1248.	2145.	2847.	3705.	4388.	-18.1	0.0	0.0	0.0	0.0	0.0
213	SI	1209.	2340.	3354.	4036.	5850.	-18.4	0.0	0.0	0.0	0.0	0.0
214	SI	1365.	1989.	2730.	3588.	4173.	-18.4	0.0	0.0	0.0	0.0	0.0
215	SI	936.	1911.	2691.	3393.	4173.	-18.3	0.0	0.0	0.0	0.0	0.0
216	SI	858.	1560.	2535.	3237.	4329.	-18.9	0.0	0.0	0.0	0.0	0.0
217	SI	390.	1404.	1989.	3003.	3783.	-17.6	0.0	0.0	0.0	0.0	0.0
218	SI	585.	1365.	2613.	3471.	4134.	-18.6	0.0	0.0	0.0	0.0	0.0
219	SI	975.	1716.	2535.	3159.	4095.	-18.3	0.0	0.0	0.0	0.0	0.0
220	SI	312.	1209.	1950.	2730.	3432.	-17.9	0.0	0.0	0.0	0.0	0.0
221	SI	858.	1833.	2652.	3432.	4173.	-16.1	0.0	0.0	0.0	0.0	0.0
222	SI	1833.	2496.	3627.	4485.	5031.	-18.2	0.0	0.0	0.0	0.0	0.0
223	SI	897.	1716.	2574.	3159.	4017.	-18.2	0.0	0.0	0.0	0.0	0.0
224	SI	390.	1209.	2106.	2925.	4290.	-18.5	0.0	0.0	0.0	0.0	0.0
225	SI	1170.	1950.	3276.	4173.	5109.	-17.9	0.0	0.0	0.0	0.0	0.0
226	SI	351.	1248.	2145.	3081.	3354.	-17.7	0.0	0.0	0.0	0.0	0.0
227	SI	546.	1287.	1950.	2613.	3510.	-17.3	0.0	0.0	0.0	0.0	0.0
228	SI	429.	1794.	2847.	3783.	4524.	-17.4	0.0	0.0	0.0	0.0	0.0
229	SI	468.	1482.	2457.	3120.	3861.	-18.2	0.0	0.0	0.0	0.0	0.0
230	SI	390.	1248.	2106.	2769.	3666.	-17.2	0.0	0.0	0.0	0.0	0.0

APPENDIX B

The Trace of the Parse for the Utterance 'What Little Brass Parts Are in the Box?'

PP8 - What little brass parts are in the box?

```
ENTER PARSE CLAUSE AT LOCATION 8
   1 INITSTRING 200
   2 "INITSTRING" 950
2 ("INITSTRING") 950 1
   3 DECLAR 570
   4 IMPER 912
   5 QUEST 912
5 (QUEST "INITSTRING") 912 3
   6 WHQUEST 875
   7 POLAR 875
4 (IMPER "INITSTRING") 912 4
   8 EMPHATIC 182
   9 NEG 182
   10 SIMPLE 875
10 (SIMPLE IMPER "INITSTRING") 875 6
   11 BE 175
   12 SIMP 840
7 (POLAR QUEST "INITSTRING") 875 7
   13 DOAUX 437
   14 MODALAUX 175
   15 HAVEAUX 175
   16 BEAUX 831
6 (WHQUEST QUEST "INITSTRING") 875 10
   17 WHNG 840
   18 WHPREP 175
   19 HOWADJ 175
17 (WHNG WHQUEST QUEST) 840 12
ENTER PARSE NGROUP AT LOCATION 8
ENTER FAMILY FOR WHNGSIMP AT LOCATION 8
NEW FAMILY CREATED
   20 NIL 840
20 NIL 840 12
ENTER PARSE WHNGSIMP AT LOCATION 8
   21 HOWQ 806
   22 WHADJ 168
   23 QDET 806
   24 QPRON 168
12 (SIMP SIMPLE IMPER) 840 15
   25 *WORD* 815
16 (BEAUX POLAR QUEST) 831 15
   26 *WORD* 815
```

```
25 (*WORD* SIMP SIMPLE) 815 15
AC      USE 8 0.0
   25 *WORD* 815
25 (*WORD* SIMP SIMPLE) 815 15
AC      UNSCREW 8 0.0
   25 *WORD* 815
25 (*WORD* SIMP SIMPLE) 815 15
AC      SCREW 8 0.0
   25 *WORD* 815
25 (*WORD* SIMP SIMPLE) 815 15
AC      PUT 8 0.0
   25 *WORD* 815
25 (*WORD* SIMP SIMPLE) 815 15
      PLACE 8 0.0
   25 *WORD* 815
25 (*WORD* SIMP SIMPLE) 815 15
AC      PICK 8 0.0
   25 *WORD* 815
25 (*WORD* SIMP SIMPLE) 815 15
AC      GRASP 8 0.0
26 (*WORD* BEAUX POLAR) 815 14
AC      IS 8 0.0
   26 *WORD* 815
26 (*WORD* BEAUX POLAR) 815 14
AC      ARE 8 1.125 11 22
   26 *WORD* 916
26 (*WORD* BEAUX POLAR) 916 14
   27 ARE 916
27 (ARE BEAUX POLAR) 916 14
   28 VG-MODIFIERS 183
   29 "VG-MODIFIERS" 871
29 ("VG-MODIFIERS" ARE BEAUX) 871 15
   30 NG 853
   31 THERE 836
30 (NG "VG-MODIFIERS" ARE) 853 16
   32 NOT-REL 845
32 (NOT-REL NG "VG-MODIFIERS") 845 16
ENTER PARSE NGROUP AT LOCATION 22
ENTER FAMILY FOR NGSIMP AT LOCATION 22
NEW FAMILY CREATED
   33 NIL 845
33 NIL 845 16
ENTER PARSE NGSIMP AT LOCATION 22
   34 ART 811
   35 DEMADJ 507
   36 POSSADJ 169
   37 QNTFR 507
   38 NUMD 507
   39 NUMCOMPAR 169
   40 ATPHRASE 169
   41 ASPHRASE 169
   42 PROPN 169
```

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    43 PRON 811
    44 THINGPRON 169
    45 EVERPRON 169
    46 POSSPRON 169
    47 POSSN 169
    48 NULL 507
 31 (THERE "VG-MODIFIERS" ARE) 836 30
    49 *WORD* 811
 43 (PRON) 811 30
    50 *WORD* 0
 34 (ART) 811 30
    51 *WORD* 795
 49 (*WORD* THERE "VG-MODIFIERS") 811 30
 AC      THERE 22 0.0
 23 (QDET) 806 29
    52 *WORD* 782
 21 (HOWQ) 806 29
    53 *WORD* 782
 51 (*WORD* ART) 795 29
 AC      THE 22 1.010714 27 37
    51 *WORD* 803
 51 (*WORD* ART) 803 29
    54 THE 803
    51 *WORD* 0
 54 (THE ART) 803 30
    55 ORD 160
    56 "ORD" 763
 53 (*WORD* HOWQ) 782 31
 AC      HOW 8 .6 11 22
    53 *WORD* 469
 52 (*WORD* QDET) 782 31
 AC      WHAT 8 1.4 11 26
    52 *WORD* 1095
 52 (*WORD* QDET) 1095 31
    57 WHAT 1095
 57 (WHAT QDET) 1095 31
    58 NUM 657
    59 "NUM" 1040
 59 ("NUM" WHAT QDET) 1040 32
    60 ADJNOUN 988
    61 "ADJNOUN" 208
 60 (ADJNOUN "NUM" WHAT) 988 33
    62 ADJSTRING 890
    63 "ADJSTRING" 939
 63 ("ADJSTRING" ADJNOUN "NUM") 939 34
    64 NOUN 901
    65 CLASSIFIER 901
 65 (CLASSIFIER "ADJSTRING" ADJNOUN) 901 35
    66 *WORD* 883
 64 (NOUN "ADJSTRING" ADJNOUN) 901 35
    67 *WORD* 883
 62 (ADJSTRING ADJNOUN "NUM") 890 35
```

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   68 ADV 178
   69 "ADV" 645
67 (*WORD* NOUN "ADJSTRING") 883 36
AC      WRENCH 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
AC      WASHER 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
AC      TOOL 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
      THING 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
      TABLE 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
      SINK 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
AC      SCREWDRIVER 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
AC      SCREW 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
      PLUG 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
      PIPE 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
AC      PART 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 36
AC      ONE 26 1.6 27 41
   67 *WORD* 1414
67 (*WORD* NOUN "ADJSTRING") 1414 36
   70 ONE 1414
   67 *WORD* 883
70 (ONE NOUN "ADJSTRING") 1414 37
EXIT PARSE (WHNGSIMP WHNG QDET ANAPHOR SINGULAR)
   71 ONE 1487 FROM 17
71 (ONE NOUN "ADJSTRING") 1487 37
   72 ENDINGS 669
   73 "ENDINGS" 1413
73 ("ENDINGS" ONE NOUN) 1413 38
EXIT PARSE (NGROUP WHNGSIMP WHNG QDET ANAPHOR SINGULAR)
   74 FULLFORM 1342
   75 "FULLFORM" 282
74 (FULLFORM "ENDINGS" ONE) 1342 39
```

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   74 FULLFORM 1342
74 (FULLFORM "ENDINGS" ONE) 1342 39
   76 AUX 1288
   77 NOAUX 805
76 (AUX FULLFORM "ENDINGS") 1288 40
   78 DOAUX 644
   79 MODALAUX 257
   80 HAVEAUX 257
   81 BEAUX 1224
81 (BEAUX AUX FULLFORM) 1224 43
   82 *WORD* 1199
82 (*WORD* BEAUX AUX) 1199 43
AC      IS 41 0.0
   82 *WORD* 1199
82 (*WORD* BEAUX AUX) 1199 43
AC      ARE 41 1.25 43 49
   82 *WORD* 1499
82 (*WORD* BEAUX AUX) 1499 43
   83 ARE 1499
83 (ARE BEAUX AUX) 1499 43
   84 VG-MODIFIERS 299
   85 "VG-MODIFIERS" 1424
85 ("VG-MODIFIERS" ARE BEAUX) 1424 44
   86 NOTWHSUBJ 854
   87 WHSUBJ 1396
87 (WHSUBJ "VG-MODIFIERS" ARE) 1396 45
67 (*WORD* NOUN "ADJSTRING") 883 44
AC      HOLE 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 44
AC      HANDLE 26 1.6 23 49
   67 *WORD* 1414
67 (*WORD* NOUN "ADJSTRING") 1414 44
   88 HANDLE 1414
   67 *WORD* 883
88 (HANDLE NOUN "ADJSTRING") 1414 45
EXIT PARSE (WHNGSIMP WHNG QDET SINGULAR)
   89 HANDLE 1487 FROM 17
89 (HANDLE NOUN "ADJSTRING") 1487 45
   90 ENDINGS 669
   91 "ENDINGS" 1413
91 ("ENDINGS" HANDLE NOUN) 1413 46
EXIT PARSE (NGROUP WHNGSIMP WHNG QDET SINGULAR)
   92 FULLFORM 1342
   93 "FULLFORM" 282
92 (FULLFORM "ENDINGS" HANDLE) 1342 47
   92 FULLFORM 1342
92 (FULLFORM "ENDINGS" HANDLE) 1342 47
   94 AUX 1288
   95 NOAUX 805
94 (AUX FULLFORM "ENDINGS") 1288 48
   96 DOAUX 644
```

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   97 MODALAUX 257
   98 HAVEAUX 257
   99 BEAUX 1224
99 (BEAUX AUX FULLFORM) 1224 51
   100 *WORD* 1199
100 (*WORD* BEAUX AUX) 1199 51
AC       IS 49 0.0
   100 *WORD* 1199
100 (*WORD* BEAUX AUX) 1199 51
AC       ARE 49 0.0
67 (*WORD* NOUN "ADJSTRING") 883 50
AC       FAUCET 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 50
AC       CAPNUT 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 50
AC       BOX 26 0.0
   67 *WORD* 883
67 (*WORD* NOUN "ADJSTRING") 883 50
AC       BOLT 26 0.0
   67 *WORD* 856
66 (*WORD* CLASSIFIER "ADJSTRING") 883 50
AC       TOOL 26 0.0
   66 *WORD* 883
66 (*WORD* CLASSIFIER "ADJSTRING") 883 50
         PIPE 26 0.0
   66 *WORD* 883
66 (*WORD* CLASSIFIER "ADJSTRING") 883 50
AC       CRESCENT 26 0.0
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       WRENCHES 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       WASHERS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       TOOLS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
         THINGS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
         TABLES 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
         SINKS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       SCREWS 26 0.0
   67 *WORD* 856
(*WORD* NOUN "ADJSTRING") 856 49
```

```
AC       SCREWDRIVERS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
      PLUGS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
      PIPES 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       PARTS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       HOLES 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
ACAC       HANDLES 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       FAUCETS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       CAPNUTS 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       BOXES 26 0.0
   67 *WORD* 856
67 (*WORD* NOUN "ADJSTRING") 856 49
AC       BOLTS 26 0.0
86 (NOTWHSUBJ "VG-MODIFIERS" ARE) 854 48
   101 NG 837
   102 THERE 492
69 ("ADV" ADJSTRING ADJNOUN) 845 49
   103 ADJ 811
   104 NUMQUANTITY 169
   105 ADJSUP 169
   106 ADJCOM 169
101 (NG NOTWHSUBJ "VG-MODIFIERS") 837 52
   107 NOT-REL 829
107 (NOT-REL NG NOTWHSUBJ) 829 52
ENTER PARSE NGROUP AT LOCATION 49
ENTER FAMILY FOR NGSIMP AT LOCATION 49
NEW FAMILY CREATED
   108 NIL 829
108 NIL 829 52
ENTER PARSE NGSIMP AT LOCATION 49
   109 ART 796
   110 DEMADJ 497
   111 POSSADJ 165
   112 QNTFR 497
   113 NUMD 497
   114 NUMCOMPAR 165
   115 ATPHRASE 165
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   116 ASPHRASE 165
    117 PROPN 165
    118 PRON 796
    119 THINGPRON 165
    120 EVERPRON 165
    121 POSSPRON 165
    122 POSSN 165
    123 NULL 497
103 (ADJ "ADV" ADJSTRING) 811 66
    124 OADJ 779
    125 VB-EN 162
    126 VB-ING 162
95 (NOAUX FULLFORM "ENDINGS") 805 68
    127 VG-MODIFIERS 161
    128 "VG-MODIFIERS" 765
77 (NOAUX FULLFORM "ENDINGS") 805 69
    129 VG-MODIFIERS 161
    130 "VG-MODIFIERS" 765
118 (PRON) 796 70
    131 *WORD* 0
109 (ART) 796 70
    132 *WORD* 780
132 (*WORD* ART) 780 70
AC       THE 49 1.25 50 63
    132 *WORD* 975
132 (*WORD* ART) 975 70
    133 THE 975
    132 *WORD* 0
133 (THE ART) 975 71
    134 ORD 195
    135 "ORD" 926
135 ("ORD" THE ART) 926 72
    136 NUM 556
    137 "NUM" 880
137 ("NUM" "ORD" THE) 880 73
    138 ADJSTRING 792
    139 "ADJSTRING" 836
139 ("ADJSTRING" "NUM" "ORD") 836 74
    140 NOUN 802
    141 CLASSIFIER 802
141 (CLASSIFIER "ADJSTRING" "NUM") 802 75
    142 *WORD* 786
140 (NOUN "ADJSTRING" "NUM") 802 75
    143 *WORD* 762
138 (ADJSTRING "NUM" "ORD") 792 75
    144 ADV 158
    145 "ADV" 752
142 (*WORD* CLASSIFIER "ADJSTRING") 786 76
AC       TOOL 63 0.0
    142 *WORD* 786
142 (*WORD* CLASSIFIER "ADJSTRING") 786 76
       PIPE 63 0.0
```

```
   142 *WORD* 786
142 (*WORD* CLASSIFIER "ADJSTRING") 786 76
AC      CRESCENT 63 0.0
124 (OADJ ADJ "ADV") 779 75
   146 *WORD* 755
130 ("VG-MODIFIERS" NOAUX FULLFORM) 765 75
   130 "VG-MODIFIERS" 765
130 ("VG-MODIFIERS" NOAUX FULLFORM) 765 75
128 ("VG-MODIFIERS" NOAUX FULLFORM) 765 74
   128 "VG-MODIFIERS" 765
128 ("VG-MODIFIERS" NOAUX FULLFORM) 765 74
56 ("ORD" THE ART) 763 73
   147 NUM 458
   148 "NUM" 725
143 (*WORD* NOUN "ADJSTRING") 762 74
ACAC      WRENCHES 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      WASHERS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      TOOLS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
      THINGS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
      TABLES 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
      SINKS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      SCREWS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      SCREWDRIVERS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
      PLUGS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
      PIPES 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      PARTS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      HOLES 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
ACAC      HANDLES 63 .281615 63 96
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   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      FAUCETS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      CAPNUTS 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
ACAC      B[illegible]ES 63 0.0
   143 *WORD* 762
143 (*WORD* NOUN "ADJSTRING") 762 74
AC      BOLTS 63 0.0
   143 *WORD* 214
146 (*WORD* OADJ ADJ) 755 74
AC      WORM 26 0.0
   146 *WORD* 755
146 (*WORD* OADJ ADJ) 755 74
AC      LITTLE 26 1.6 27 49
   146 *WORD* 1209
146 (*WORD* OADJ ADJ) 1209 74
   149 LITTLE 1209
   146 *WORD* 755
149 (LITTLE OADJ ADJ) 1209 75
   150 ADJSTRING 1027
   151 "ADJSTRING" 1148
151 ("ADJSTRING" LITTLE OADJ) 1148 76
   152 NOUN 1102
   153 CLASSIFIER 1102
153 (CLASSIFIER "ADJSTRING" LITTLE) 1102 77
   154 *WORD* 1080
152 (NOUN "ADJSTRING" LITTLE) 1102 77
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC      WRENCH 49 .3065143 58 81
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC      WASHER 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC      TOOL 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
        THING 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
        TABLE 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
        SINK 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC      SCREWDRIVER 49 0.0
```

```
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       SCREW 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
      PLUG 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
      PIPE 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       PART 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       ONE 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       HOLE 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       HANDLE 49 .6 50 87
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       FAUCET 49 .58493 50 81
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       CAPNUT 49 0.0
   155 *WORD* 1080
155 (*WORD* NOUN "ADJSTRING") 1080 77
AC       BOX 49 1.6 50 96
   155 *WORD* 1729
155 (*WORD* NOUN "ADJSTRING") 1729 77
   156 BOX 1729
   155 *WORD* 1080
156 (BOX NOUN "ADJSTRING") 1729 78
EXIT PARSE (WHNGSIMP WHNG QDET SINGULAR)
   157 BOX 1875 FROM 17
157 (BOX NOUN "ADJSTRING") 1875 78
   158 ENDINGS 843
   159 "ENDINGS" 1781
159 ("ENDINGS" BOX NOUN) 1781 79
EXIT PARSE (NGROUP WHNGSIMP WHNG QDET SINGULAR)
   160 FULLFORM 1692
   161 "FULLFORM" 356
160 (FULLFORM "ENDINGS" BOX) 1692 80
   160 FULLFORM 1692
160 (FULLFORM "ENDINGS" BOX) 1692 80
   162 AUX 1624
   163 NOAUX 1015
162 (AUX FULLFORM "ENDINGS") 1624 81
   164 DOAUX 612
   165 MODALAUX 324
```

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   166 HAVEAUX 324
   167 BEAUX 1543
167 (BEAUX AUX FULLFORM) 1543 84
   168 *WORD* 1512
168 (*WORD* BEAUX AUX) 1512 84
AC       IS 96 0.0
   168 *WORD* 1512
168 (*WORD* BEAUX AUX) 1512 84
AC       ARE 96 1.25 97 1.12
   168 *WORD* 1891
168 (*WORD* BEAUX AUX) 1891 84
   169 ARE 1891
169 (ARE BEAUX AUX) 1891 84
   170 VG-MODIFIERS 378
   171 "VG-MODIFIERS" 1796
171 ("VG-MODIFIERS" ARE BEAUX) 1796 85
   172 NOTWHSUBJ 1077
   173 WHSUBJ 1760
173 (WHSUBJ "VG-MODIFIERS" ARE) 1760 86
154 (*WORD* CLASSIFIER "ADJSTRING") 1080 85
AC       TOOL 49 0.0
   154 *WORD* 1080
154 (*WORD* CLASSIFIER "ADJSTRING") 1080 85
      PIPE 49 0.0
   154 *WORD* 1080
154 (*WORD* CLASSIFIER "ADJSTRING") 1080 85
AC       CRESCENT 49 0.0
155 (*WORD* NOUN "ADJSTRING") 1080 84
AC       BOLT 49 0.0
   155 *WORD* 1047
172 (NOTWHSUBJ "VG-MODIFIERS" ARE) 1077 84
   174 NG 1056
   175 THERE 620
174 (NG NOTWHSUBJ "VG-MODIFIERS") 1056 85
   176 NOT-REL 1045
155 (*WORD* NOUN "ADJSTRING") 1047 85
ACAC       WRENCHES 49 0.0
   155 *WORD* 1047
155 (*WORD* NOUN "ADJSTRING") 1047 85
AC       WASHERS 49 0.0
   155 *WORD* 1047
155 (*WORD* NOUN "ADJSTRING") 1047 85
AC       TOOLS 49 0.0
   155 *WORD* 1047
155 (*WORD* NOUN "ADJSTRING") 1047 85
      THINGS 49 0.0
   155 *WORD* 1047
155 (*WORD* NOUN "ADJSTRING") 1047 85
      TABLES 49 0.0
   155 *WORD* 1047
155 (*WORD* NOUN "ADJSTRING") 1047 85
      SINKS 49 0.0
```

```
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 AC       SCREWS 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 AC       SCREWDRIVERS 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
       PLUGS 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
       PIPES 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 AC       PARTS 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 AC       HOLES 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 ACAC       HANDLES 49 .45 50 96
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 ACAC       FAUCETS 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 AC       CAPNUTS 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 ACAC       BOXES 49 0.0
   155 *WORD* 1047
 155 (*WORD* NOUN "ADJSTRING") 1047 85
 AC       BOLTS 49 0.0
   155 *WORD* 648
276 (NOT-REL NG NOTWHSUBJ) 1045 85
ENTER PARSE NGROUP AT LOCATION 112
ENTER FAMILY FOR NGSIMP AT LOCATION 112
NEW FAMILY CREATED
   177 NIL 1045
177 NIL 1045 85
ENTER PARSE NGSIMP AT LOCATION 112
   178 ART 1003
   179 DEMADJ 627
   180 POSSADJ 209
   181 QNTFR 627
   182 NUMD 627
   183 NUMCOMPAR 209
   184 ATPHRASE 209
   185 ASPHRASE 209
   186 PROPN 209
   187 PRON 1003
   188 THINGPRON 209
```

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   189 EVERPRON 209
   190 POSSPRON 209
   191 POSSN 209
   192 NULL 627
150 (ADJSTRING LITTLE OADJ) 1027 99
   193 ADV 205
   194 "ADV" 976
163 (NOAUX FULLFORM "ENDINGS") 1015 100
   195 VG-MODIFIERS 203
   196 "VG-MODIFIERS" 964
187 (PRON) 1003 101
   197 *WORD* 0
176 (ART) 1003 101
   198 *WORD* 983
198 (*WORD* ART) 983 101
AC      THE 112 .33 124 131
   198 *WORD* 324
194 ("ADV" ADJSTRING LITTLE) 976 101
   199 ADJ 937
   200 NUMQUANTITY 195
   201 ADJSUP 195
   202 ADJCOM 195
196 ("VG-MODIFIERS" NOAUX FULLFORM) 964 104
   196 "VG-MODIFIERS" 964
196 ("VG-MODIFIERS" NOAUX FULLFORM) 964 104
199 (ADJ "ADV" ADJSTRING) 937 103
   203 OADJ 899
   204 VB-EN 187
   205 VB-ING 187
203 (OADJ ADJ "ADV") 899 105
   206 *WORD* 872
206 (*WORD* OADJ ADJ) 872 105
AC      WORN 49 0.0
   206 *WORD* 872
206 (*WORD* OADJ ADJ) 872 105
AC      LITTLE 49 0.0
   206 *WORD* 872
206 (*WORD* OADJ ADJ) 872 105
AC      BRASS 49 1.6 50 81
   206 *WORD* 1396
206 (*WORD* OADJ ADJ) 1396 105
   207 BRASS 1396
   206 *WORD* 872
207 (BRASS OADJ ADJ) 1396 106
   208 ADJSTRING 1117
   209 "ADJSTRING" 1326
209 ("ADJSTRING" BRASS OADJ) 1326 107
   210 NOUN 1273
   211 CLASSIFIER 1273
211 (CLASSIFIER "ADJSTRING" BRASS) 1273 108
   212 *WORD* 1248
210 (NOUN "ADJSTRING" BRASS) 1273 108
```

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   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
AC       WRENCH 81 .1584 97 122
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
AC       WASHER 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
AC       TOOL 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
       THING 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
       TABLE 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
       SINK 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
AC       SCREWDRIVER 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
AC       SCREW 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
       PLUG 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
       PIPE 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 108
AC       PART 81 1.6 82 114
   213 *WORD* 1997
213 (*WORD* NOUN "ADJSTRING") 1997 108
   214 PART 1997
   213 *WORD* 1248
214 (PART NOUN "ADJSTRING") 1997 109
EXIT PARSE (WHNGSIMP WHNG QDET SINGULAR)
   215 PART 2233 FROM 17
215 (PART NOUN "ADJSTRING") 2233 109
   216 ENDINGS 1004
   217 "ENDINGS" 2121
217 ("ENDINGS" PART NOUN) 2121 110
EXIT PARSE (NGROUP WHNGSIMP WHNG QDET SINGULAR)
   218 FULLFORM 2015
   219 "FULLFORM" 424
218 (FULLFORM "ENDINGS" PART) 2015 111
   218 FULLFORM 2015
218 (FULLFORM "ENDINGS" PART) 2015 111
   220 AUX 1934
   221 NOAUX 1209
```

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220 (AUX FULLFORM "ENDINGS") 1934 112
   222 DOAUX 967
   223 MODALAUX 386
   224 HAVEAUX 386
   225 BEAUX 1838
225 (BEAUX AUX FULLFORM) 1038 115
   226 *WORD* 1801
226 (*WORD* BEAUX AUX) 1801 115
AC       IS 114 0.0
   226 *WORD* 1801
226 (*WORD* BEAUX AUX) 1801 115
AC       ARE 114 0.0
212 (*WORD* CLASSIFIER "ADJSTRING") 1248 114
AC       TOOL 81 0.0
   212 *WORD* 1248
212 (*WORD* CLASSIFIER "ADJSTRING") 1248 114
         PIPE 81 0.0
   212 *WORD* 1248
212 (*WORD* CLASSIFIER "ADJSTRING") 1248 114
AC       CRESCENT 81 0.0
213 (*WORD* NOUN "ADJSTRING") 1248 113
AC       ONE 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 113
AC       HOLE 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 113
AC       HANDLE 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 113
AC       FAUCET 81 .528 91 150
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 113
AC       CAPNUT 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 113
AC       BOX 81 0.0
   213 *WORD* 1248
213 (*WORD* NOUN "ADJSTRING") 1248 113
AC       BOLT 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
ACAC       WRENCHES 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
AC       WASHERS 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
AC       TOOLS 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
         THINGS 81 0.0
```

```
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
      TABLES 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
      SINKS 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
AC       SCREWS 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
AC       SCREWDRIVERS 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
      PLUGS 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
      PIPES 81 0.0
   213 *WORD* 1210
213 (*WORD* NOUN "ADJSTRING") 1210 113
ACAC       PARTS 81 1.6 82 122
   213 *WORD* 1936
213 (*WORD* NOUN "ADJSTRING") 1936 113
   227 PARTS 1936
   213 *WORD* 1210
227 (PARTS NOUN "ADJSTRING") 1936 114
EXIT PARSE (WHNGSIMP WHNG QDET PLURAL)
   228 PARTS 2233 FROM 17
228 (PARTS NOUN "ADJSTRING") 2233 114
   229 ENDINGS 1004
   230 "ENDINGS" 2121
230 ("ENDINGS" PARTS NOUN) 2121 115
EXIT PARSE (NGROUP WHNGSIMP WHNG QDET PLURAL)
   231 FULLFORM 2015
   232 "FULLFORM" 424
231 (FULLFORM "ENDINGS" PARTS) 2015 116
   231 FULLFORM 2015
231 (FULLFORM "ENDINGS" PARTS) 2015 116
   233 AUX 1934
   234 NOAUX 1209
233 (AUX FULLFORM "ENDINGS") 1934 117
   235 DOAUX 957
   236 MODALAUX 386
   237 HAVEAUX 386
   238 BEAUX 1838
238 (BEAUX AUX FULLFORM) 1838 120
   239 *WORD* 1801
239 (*WORD* BEAUX AUX) 1801 120
AC       IS 122 0.0
   239 *WORD* 1801
239 (*WORD* BEAUX AUX) 1801 120
AC       ARE 122 1.130357 126 137
```

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   239 *WORD* 2036
239 (*WORD* BEAUX AUX) 2036 120
   240 ARE 2036
240 (ARE BEAUX AUX) 2036 120
   241 VG-MODIFIERS 407
   242 "VG-MODIFIERS" 1934
242 ("VG-MODIFIERS" ARE BEAUX) 1934 121
   243 NOTWHSUBJ 1160
   244 WHSUBJ 1895
244 (WHSUBJ "VG-MODIFIERS" ARE) 1895 122
   244 WHSUBJ 1895
244 (WHSUBJ "VG-MODIFIERS" ARE) 1895 122
   245 THERE 1516
   246 "THERE" 1800
246 ("THERE" WHSUBJ "VG-MODIFIERS") 1800 123
   247 PROGRESSIVE 360
   248 PASS 360
   249 COP 1530
249 (COP "THERE" WHSUBJ) 1530 125
   250 NGROUP 918
   251 ADJCOMPL 1469
   252 PREPCOMPL 1469
245 (THERE WHSUBJ "VG-MODIFIERS") 1516 127
   253 *WORD* 1471
253 (*WORD* THERE WHSUBJ) 1471 127
AC       THERE 137 1.25 137 148
   253 *WORD* 1838
253 (*WORD* THERE WHSUBJ) 1838 127
   254 THERE 1838
254 (THERE THERE WHSUBJ) 1838 127
   255 PROGRESSIVE 367
   256 PASS 367
   257 COP 1562
257 (COP THERE THERE) 1562 129
   258 PGCOMP 1500
   259 NOCOMP 1500
259 (NOCOMP COP THERE) 1500 130
258 (PGCOMP COP THERE) 1500 129
ENTER PARSE PREPG AT LOCATION 148
   260 *WORD* 1455
252 (PREPCOMPL COP "THERE") 1469 129
   261 *WORD* 1425
251 (ADJCOMPL COP "THERE") 1469 129
ENTER PARSE ADJG AT LOCATION 137
   262 COMPAR 293
   263 AS-ADJ-AS 293
   264 THE-SAME-AS 293
   265 ADJCOMPL 1410
260 (*WORD* PGCOMP COP) 1455 132
AC       WITH 148 0.0
   260 *WORD* 1455
260 (*WORD* PGCOMP COP) 1455 132
```

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AC       ON 148 .5321429 157 178
   260 *WORD* 1455
260 (*WORD* PGCOMP COP) 1455 132
AC       IN 148 0.0
   260 *WORD* 1455
260 (*WORD* PGCOMP COP) 1455 132
      FROM 148 0.0
   260 *WORD* 1455
260 (*WORD* PGCOMP COP) 1455 132
AC       BETWEEN 148 0.0
   260 *WORD* 1455
260 (*WORD* PGCOMP COP) 1455 132
      BEHIND 148 0.0
   260 *WORD* 774
261 (*WORD* PREPCOMPL COP) 1425 132
AC       WITH 137 0.0
   261 *WORD* 1425
261 (*WORD* PREPCOMPL COP) 1425 132
AC       ON 137 0.0
   261 *WORD* 1425
261 (*WORD* PREPCOMPL COP) 1425 132
AC       IN 137 1.25 132 145
   261 *WORD* 1781
261 (*WORD* PREPCOMPL COP) 1781 132
   266 IN 1781
   261 *WORD* 1425
266 (IN PREPCOMPL COP) 1781 133
ENTER PARSE NGROUP AT LOCATION 145
ENTER FAMILY FOR NGSIMP AT LOCATION 145
NEW FAMILY CREATED
   267 NIL 1781
267 NIL 1781 133
ENTER PARSE NGSIMP AT LOCATION 145
   268 ART 1710
   269 DEMADJ 1069
   270 POSSADJ 356
   271 QNTFR 1069
   272 NUMD 1069
   273    COMPAR 356
   274 ATPHRASE 356
   275 ASPHRASE 356
   276 PROPN 356
   277 PRON 1710
   278 THINGPRON 356
   279 EVERPRON 356
   280 POSSPRON 356
   281 POSSN 356
   282 NULL 1069
277 (PRON) 1710 147
   283 *WORD* 1676
268 (ART) 1710 147
   284 *WO D* 1676
```

```
284 (*WORD* ART) 1676 147
AC      THE 145 1.25 137 148
   284 *WORD* 2095
284 (*WORD* ART) 2095 147
   285 THE 2095
   284 *WORD* 1590
285 (THE ART) 2095 148
   286 ORD 419
   287 "ORD" 1990
287 ("ORD" THE ART) 1990 149
   288 NUM 1194
   289 "NUM" 1891
289 ("NUM" "ORD" THE) 1891 150
   290 ADJSTRING 1701
   291 "ADJSTRING" 1796
291 ("ADJSTRING" "NUM" "ORD") 1796 151
   292 NOUN 1724
   293 CLASSIFIER 1724
293 (CLASSIFIER "ADJSTRING" "NUM") 1724 152
   294 *WORD* 1690
292 (NOUN "ADJSTRING" "NUM") 1724 152
   295 *WORD* 1690
290 (ADJSTRING "NUM" "ORD") 1701 152
   296 ADV 340
   297 "ADV" 1616
295 (*WORD* NOUN "ADJSTRING") 1690 153
       THING 148 0.0
   295 *WORD* 1690
295 (*WORD* NOUN "ADJSTRING") 1690 153
       SINK 148 0.0
   295 *WORD* 1690
295 (*WORD* NOUN "ADJSTRING") 1690 153
AC      ONE 148 0.0
   295 *WORD* 1690
295 (*WORD* NOUN "ADJSTRING") 1690 153
AC      HOLE 148 0.0
   295 *WORD* 1690
295 (*WORD* NOUN "ADJSTRING") 1690 153
AC      FAUCET 148 0.0
   295 *WORD* 1690
295 (*WORD* NOUN "ADJSTRING") 1690 153
AC      BOX 148 1.6 149 201
   295 *WORD* 2704
295 (*WORD* NOUN "ADJSTRING") 2704 153
   298 BOX 2704
   295 *WORD* 1638
298 (BOX NOUN "ADJSTRING") 2704 154
EXIT PARSE (NGSIMP DEF ART SINGULAR)
   299 BOX 2815 FROM 266
299 (BOX NOUN "ADJSTRING") 2815 154
   300 "ENDINGS" 2675
300 ("ENDINGS" BOX NOUN) 2675 154
```

```
EXIT PARSE (NGROUP NGSIMP DEF ART SINGULAR)
   300 "ENDINGS" 2675
300 ("ENDINGS" BOX NOUN) 2675 154
EXIT PARSE (CLAUSE MAJOR QUESTION BE WHQUEST)

6:48 RUNTIME
0:17 GCTIME
25:24 REAL TIME
31775 CONSES
9881 PAGE FAULTS
LOAD AV    3.2   2.93   2.54

PATH: ("INITSTRING" QUEST WHQUEST WHNG QDET WHAT "NUM" ADJNOUN
ADJSTRING "ADV" ADJ OADJ LITTLE ADJSTRING "ADV" ADJ OADJ BRASS
"ADJSTRING" NOUN PARTS "ENDINGS" FULLFORM AUX BEAUX ARE
"VG-MODIFIERS" WHSUBJ "THERE" COP PREPCOMPL IN ART THE "ORD"
"NUM" "ADJSTRING" NOUN BOX "ENDINGS")

SYSTEM HEARD: (WHAT LITTLE BRASS PARTS ARE IN THE BOX)

RESPONSE:  2 SCREWS

PARSE TREE
(CLAUSE MAJOR QUESTION BE WHQUEST)
   SUBJECT: FOCUSELT: (NGROUP WHNGSIMP WHNG QDET PLURAL)
      (WHNGSIMP WHNG QDET PLURAL)
         WHAT (QDET)
         LITTLE (ADJ)
         BRASS (ADJ)
         PARTS (PLURAL NOUN)
   MVB: ARE (BE PLURAL PRESENT TENSEDVERB)
   GOALPP: IN (PREP)
   COMPLEMENT: (NGROUP NGSIMP DEF ART SINGULAR)
      (NGSIMP DEF ART SINGULAR)
         THE (DEF ART)
         BOX (SINGULAR NOUN)

INPUT START = 8
INPUT END = 201

WORDS GETTING NONZERO VERIFICATION DURING PARSE
8   ARE .9 11 22
    HOW .5 11 22
    WHAT .9 11 26
22  THE 1.0 27 37
26  ONE 1.0 27 41
    HANDL 1.0 23 49 2
    LITTL 1.0 27 49
41  ARE 1.0 43 49
49  THE 1.0 50 63
    WRENC .56 58 81 2
    HANDL .5 50 87 2
```

```
     FAUCE .49248 50 81 2
     BOX 1.0 50 96 2
     BRASS 1.0 50 81
63   WRENC .56 60 81
     HANDL .40095 63 87
     BOX 1.0 50 96
81   WRENC .8 97 122 2
     PART 1.0 82 114 2
     FAUCE 1.0 91 150
87   PLZ .85 91 96 2
96   ARE 1.0 97 112
112  THE 1.0 124 131
114  PLS 1.0 116 122
122  ARE 1.0 126 137
137  THERE 1.0 137 145
     IN 1.0 132 145
145  THE 1.0 137 148
148  ON 1.0 157 178
     BOX 1.0 149 201
FOUND:30 TRIED:104 TIMES:141

ALL WORDS CHECKED DURING PARSE
8    USE 0.0
     UNSCR 0.0
     SCREW 0.0
     PUT 0.0
     PICK 0.0
     GRASP 0.0
     IS 0.0
     ARE .9 11 22
     HOW .5 11 22
     WHAT .9 11 26
22   THERE 0.0
     THE 1.0 27 37
26   WRENC 0.0 2
     WASHE 0.0 2
     TOOL 0.0 3
     SDRIV 0.0 2
     SCREW 0.0 2
     PART 0.0 2
     ONE 1.0 27 41
     HOLE 0.0 2
     HANDL 1.0 23 49 2
     FAUCE 0.0 2
     CAPNU 0.0 2
     BOX 0.0 2
     BOLT 0.0 2
     CRESC 0.0
     WORN 0.0
     LITTL 1.0 27 49
41   IS 0.0
     ARE 1.0 43 49
```

```
49  IS 0.0
    ARE 0.0
    PLZ 0.0
    THE 1.0 50 63
    WRENC .56 58 81 2
    WASHE 0.0 2
    TOOL 0.0 3
    SDRIV 0.0 2
    SCREW 0.0 2
    PART 0.0 2
    ONE 0.0
    HOLE 0.0 2
    HANDL .5 50 87 2
    FAUCE .49248 50 81 2
    CAPNU 0.0 2
    BOX 1.0 50 96 2
    CRESC 0.0
    BOLT 0.0 2
    WORN 0.0
    LITTL 0.0
    BRASS 1.0 50 81
63  TOOL 0.0 2
    CRESC 0.0
    WRENC .56 60 81
    WASHE 0.0
    SCREW 0.0
    SDRIV 0.0
    PART 0.0
    HOLE 0.0
    HANDL .40095 63 87
    FAUCE 0.0
    CAPNU 0.0
    BOX 1.0 50 96
    BOLT 0.0
81  PLES 0.0 2
    PLS 0.0
    WRENC .8 97 122 2
    WASHE 0.0 2
    TOOL 0.0 3
    SDRIV 0.0 2
    SCREW 0.0 2
    PART 1.0 82 114 2
    CRESC 0.0
    ONE 0.0
    HOLE 0.0
    HANDL 0.0
    FAUCE 1.0 91 150
    CAPNU 0.0
    BOX 0.0
    BOLT 0.0
87  PLZ .85 91 96 2
96  PLES 0.0 2
```

```
    IS 0.0
    ARE 1.0 97 112
112 THE 1.0 124 131
114 IS 0.0
    ARE 0.0
    PLS 1.0 116 122
122 PLES 0.0
    IS 0.0
    ARE 1.0 126 137
137 THERE 1.0 137 148
    WITH 0.0
    ON 0.0
    IN 1.0 132 145
145 THE 1.0 137 148
148 WITH 0.0
    ON 1.0 157 178
    IN 0.0
    BETWE 0.0
    ONE 0.0
    HOLE 0.0
    FAUCE 0.0
    BOX 1.0 149 201
FOUND:30 TRIED:104 TIMES:141
```

APPENDIX C

The Successful Path of the Parse for the Utterance

'What Little Brass Parts Are in the Box?'

PP8 - What little brass parts are in the box?

```
ENTER PARSE CLAUSE AT LOCATION 8
2 ("INITSTRING") 950 1
5 (QUEST "INITSTRING") 912 3
6 (WHQUEST QUEST "INITSTRING") 875 10
17 (WHNG WHQUEST QUEST) 840 12
ENTER PARSE NGROUP AT LOCATION 8
ENTER FAMILY FOR WHNGSIMP AT LOCATION 8
NEW FAMILY CREATED
ENTER PARSE WHNGSIMP AT LOCATION 8
23 (QDET) 806 29
52 (*WORD* QDET) 782 31
AC       WHAT 8 1.4 11 26
57 (WHAT QDET) 1095 31
59 ("NUM" WHAT QDET) 1040 32
60 (ADJNOUN "NUM" WHAT) 988 33
62 (ADJSTRING ADJNOUN "NUM") 890 35
69 ("ADV" ADJSTRING ADJNOUN) 845 49
103 (ADJ "ADV" ADJSTRING) 811 66
124 (OADJ ADJ "ADV") 779 75
146 (*WORD* OADJ ADJ) 755 74
AC       LITTLE 26 1.6 27 49
149 (LITTLE OADJ ADJ) 1209 75
150 (ADJSTRING LITTLE OADJ) 1027 99
194 ("ADV" ADJSTRING LITTLE) 976 101
199 (ADJ "ADV" ADJSTRING) 937 103
203 (OADJ ADJ "ADV") 899 105
206 (*WORD* OADJ ADJ) 872 105
AC       BRASS 49 1.6 50 81
207 (BRASS OADJ ADJ) 1396 106
209 ("ADJSTRING" BRASS OADJ) 1326 107
210 (NOUN "ADJSTRING" BRASS) 1273 108
213 (*WORD* NOUN "ADJSTRING") 1210 113
ACAC       PARTS 81 1.6 82 122
227 (PARTS NOUN "ADJSTRING") 1936 114
EXIT PARSE (WHNGSIMP WHNG QDET PLURAL)
   228 PARTS 2233 FROM 17
228 (PARTS NOUN "ADJSTRING") 2233 114
230 ("ENDINGS" PARTS NOUN) 2121 115
EXIT PARSE (NGROUP WHNGSIMP WHNG QDET PLURAL)
231 (FULLFORM "ENDINGS" PARTS) 2015 116
233 (AUX FULLFORM "ENDINGS") 1934 117
```

```
238 (BEAUX AUX FULLFORM) 1838 120
239 (*WORD* BEAUX AUX) 1801 120
AC      ARE 122 1.130357 126 137
240 (ARE BEAUX AUX) 2036 120
242 ("VG-MODIFIERS" ARE BEAUX) 1934 121
244 (WHSUBJ "VG-MODIFIERS" ARE) 1895 122
246 ("THERE" WHSUBJ "VG-MODIFIERS") 1800 123
249 (COP "THERE" WHSUBJ) 1530 125
252 (PREPCOMPL COP "THERE") 1469 129
261 (*WORD* PREPCOMPL COP) 1425 132
AC      IN 137 1.25 132 145
266 (IN PREPCOMPL COP) 1781 133
ENTER PARSE NGROUP AT LOCATION 145
ENTER FAMILY FOR NGSIMP AT LOCATION 145
NEW FAMILY CREATED
ENTER PARSE NGSIMP AT LOCATION 145
268 (ART) 1710 147
AC      THE 145 1.25 137 148
285 (THE ART) 2095 148
287 ("ORD" THE ART) 1990 149
289 ("NUM" "ORD" THE) 1891 150
291 ("ADJSTRING" "NUM" "ORD") 1796 151
292 (NOUN "ADJSTRING" "NUM") 1724 152
295 (*WORD* NOUN "ADJSTRING") 1690 153
AC      BOX 148 1.6 149 201
298 (BOX NOUN "ADJSTRING") 2704 154
EXIT PARSE (NGSIMP DEF ART SINGULAR)
   299 BOX 2815 FROM 266
299 (BOX NOUN "ADJSTRING") 2815 154
300 ("ENDINGS" BOX NOUN) 2675 154
EXIT PARSE (NGROUP NGSIMP DEF ART SINGULAR)
300 ("ENDINGS" BOX NOUN) 2675 154
EXIT PARSE (CLAUSE MAJOR QUESTION BE WHQUEST)
```

APPENDIX D

Sentences Recorded for the 'Faucet World' Task Domain*

Group H	0	Grasp it between the two holes.
	1	Now bolt the parts together.
	2	Does the bolt fit in the hole?
	3	Can you grasp a bolt by the head?
	4	Please grasp it now.
	5	Grasp the part with a hole between the bolts.
	6	Bolt the two two inch bolts together.
	7	Put two holes together to grasp.
	8	Now it can be put together.
	9	Put a part between a hole and the part.
Group I	0	Grasp two wingbolts together.
	1	Bolt it now with two parts.
	2	Will it fit between the holes?
	3	Can you now grasp the part?
	4	Can you put it together now?
	5	Now put it between two new parts.
	6	Move a hole between them.
	7	Place two bolts together.
	8	Between one and two inches.
	9	Now we've got it all together.
Group J	0	Fix the worn faucet later.
	1	Now unscrew the old screw.
	2	Now fix two worn valves.
	3	Next unscrew an old bolt.
	4	Fix a new valve in the faucet.
	5	Then we can screw on a new one.
	6	Can we fix the same old faucet?
	7	After we bolt it you can fix it.
	8	Turn off the same valve later.
	9	Then turn on the next valve.

----

*The sentences in Groups H through S were recorded by two speakers. Group N was recorded a second time by the same speakers as if in response to a request from the system to repeat their first utterances. The first three sentences in Group Z were recorded by the previous two speakers and by a third one. The latter alone recorded the fourth sentence in that Group.

Group K	0	Turn off the same faucet.
	1	I bolted an old one on.
	2	Then I fixed the new valve.
	3	Next I unscrewed the same one.
	4	Can you screw it on later?
	5	Unscrew one after we fix it.
	6	Will you turn off the next valve?
	7	We unscrewed it later on.
	8	Turn the faucet off and on.
	9	The worn one screws on next.
Group L	0	Put a screw in the hole.
	1	Did you put a screw in the hole?
	2	Turn the screw two turns.
	3	What part is in the hole?
	4	I put a worn bolt in.
	5	Put the new faucet together.
	6	Now put a valve in between.
	7	After that grasp a bolt.
	8	After you fix the same part.
	9	Can we fix a worn valve?
Group M	0	I grasped the old part.
	1	You put one on later.
	2	We unscrewed it after that.
	3	Now turn off the old parts.
	4	After you turn the old one.
	5	Then I can grasp two.
	6	Now put in the same bolt.
	7	Turn a new and old screw.
	8	Then unscrew one later.
	9	The worn faucet's next.
Group N	0	Grasp the handle with a hole in it.
	1	Put the handle on the faucet.
	2	Screw a big screw in the handle.
	3	Is there a crescent wrench in the box?
	4	Unscrew the capnut with the little one.
	5	Is the washer in the faucet worn?
	6	Pick up the big screwdriver.
	7	Use it to unscrew the brass screw.
	8	How many parts are there?
	9	What tools are in the box?

Group O	0	Pick up the worn crescent wrench.
	1	Where are the washers for the faucets?
	2	How many washers are in the box?
	3	There is a big screwdriver in the box.
	4	Pick up the little pipe wrench.
	5	Grasp the handle on the faucet.
	6	Use a little washer in the big box.
	7	Is the screwdriver on the worn handle?
	8	How many big tools are there?
	9	Is one a little crescent wrench?
Group P	0	Pick up the little wrench by the capnut.
	1	Pick up the big brass washer by the box.
	2	Are there many washers by the screwdriver?
	3	How many tools are on the table?
	4	Use the crescent wrench to put the capnut on.
	5	Is there a little tool in the box?
	6	Is the handle on the big bolt?
	7	What tool is used to screw things?
	8	What little brass parts are in the box?
	9	How many capnuts are on the table?
Group Q	0	The big brass part on the faucet is the handle.
	1	The little part on the handle is the capnut.
	2	There is a washer between the capnut and the handle.
	3	How is a screwdriver used?
	4	Pick up the washer by the screwdriver.
	5	Use a screwdriver to screw it in.
	6	The big tool is a crescent wrench.
	7	The little brass washer is on the table.
	8	How many big brass parts are there?
	9	What wrench is in the box?
Group R	0	Place the plug in the hole in the sink.
	1	Put the black pipe wrench on the table.
	2	Is the plug behind the box?
	3	Place it on top of the box.
	4	Place the faucet in the sink.
	5	What is in back of the faucet?
	6	What black tools are behind the box?
	7	Put the pipe wrench on top of the table.
	8	Is there a tool in back of the box?
	9	How many washers are black?

Group S	0	Screw the screw in it.
	1	Put it on the faucet.
	2	Pick up a big one.
	3	Is there a little one in the box?
	4	Is it on the box?
	5	What tools are in the big one?
	6	Unscrew a little brass one.
	7	Screw a screw in the handle with it.
	8	Unscrew the capnut with the big one.
	9	What little brass parts are in the box?

Group Z	0	Put one washer in the faucet.
	1	Grasp the crescent wrench.
	2	Is it in it?
	3	What little brass parts are in the box?

APPENDIX E

Utterances Processed by the SRI Speech Understanding System*

L0 Put a screw in the hole.
B - understood correctly
P - understood correctly

L3 What part is in the hole?
B - understood correctly
P - understood correctly

N1 Put the handle on the faucet.
B - understood correctly
P - understood correctly

N2 Screw a big screw in the handle.
B - understood correctly
P - understood correctly>

N3 Is there a crescent wrench in the box?
B - understood correctly
P - missed 'a'; exceeded limit; 'is there crescent wrench ...'

N4 Unscrew the capnut with the little one.
B - understood correctly
P - false acceptances; exceeded limit; 'unscrew the ...'

N6 Pick up the big screwdriver.
B - understood correctly
P - understood correctly

N8 How many parts are there?
B - understood correctly
P - false acceptances; exceeded limit; 'how many ...'

N9 What tools are in the box?
B - 'tool' failed
P - understood correctly

O0 Pick up the worn crescent wrench.
B - understood correctly
P - understood correctly

O2 How many washers are in the box?
B - understood correctly
P - understood 'How many wrenches are in the box?'; accepted 'washers' with lower score because of gap penalty

O3 There is a big screwdriver on the box.
B - understood correctly
P - false acceptances; exceeded limit; 'there is a big screwdriver ...'

----

*B, P, and K are speakers who recorded the utterances.

05 Grasp the handle on the faucet.
B - understood correctly
P - understood correctly

08 How many big tools are there?
B - 'there' failed; exceeded limit; 'how many big tools are ...'
P - understood 'How many big tools are on it?'; never tested for 'there'

09 Is one a little crescent wrench?
B - gap between 'is' and 'one'; 'is ... one little crescent ...'
P - priority assignment for 'one' as noun group too low; never tested for 'a'; 'is one [illegible] crescent wrench'

P5 Is there a little tool in the box?
B - understood correctly
P - understood correctly

P8 What little brass parts are in the box?
B - understood correctly
P - understood correctly

Q0 The big brass part on the faucet is the handle.
B - false acceptance of 'put' at beginning; exceeded limit before testing for 'the'; '... brass part on the faucet ...'
P - false acceptances; exceeded limit; 'the big brass part on the faucet ...'

Q1 The little part on the handle is the capnut.
B - false acceptances; exceeded limit; 'the little part on the ...'
P - 'little' failed

Q6 The big tool is a crescent wrench.
B - 'tool' failed
P - 'tool' failed

Q8 How many big brass parts are there?
B - understood 'How many big brass parts are the handle?'; error in grammar
P - understood correctly

Q9 What wrench is in the box?
B - understood correctly
P - understood correctly

S0 Screw the screw in it.
B - understood correctly
P - understood correctly

S1 Put it on the faucet.
B - understood correctly
P - understood correctly

S2 Pick up a big one.
B - understood 'Pick up a big wrench.'; had correct analysis with higher priority for path, but vocal fry at end of utterance resulted in looking for longer word
P - understood correctly

S3 Is there a little one in the box?
B - understood 'Is there a little one in the faucet?'; accepted 'faucet' in spite of low score because of high priority for path; never tested for 'box'
P - understood 'Is there a little handle in a box?'; 'one' failed
S4 Is it on the box?
B - understood correctly
P - understood correctly
S5 What tools are in the big one?
B - understood correctly
P - understood correctly
S6 Unscrew a little brass one.
B - understood correctly
P - understood correctly
S7 Screw a screw in the handle with it.
B - 'in' failed; 'screw a screw ...'
P - 'in' failed; 'screw a screw ...'
S8 Unscrew the capnut with the big one.
B - 'the' failed; 'a' accepted at that place but with low rating; exceeded limit; 'unscrew a capnut ...'
P - 'one' failed; 'unscrew the capnut with the big ...'
S9 What little brass parts are in the box?
B - 'little' failed
P - false acceptances; exceeded limit; 'what little brass parts are ...'
Z0 Put one washer in the faucet.
B - understood correctly
P - understood correctly
K - understood correctly
Z1 Grasp the crescent wrench.
P - understood correctly
K - understood correctly
Z2 Is it in it?
B - understood correctly
K - understood 'Is there a wrench?'; had correct analysis with higher priority for path, but vocal fry at end of utterance resulted in looking for longer word

ATTACHMENTS

Walker, Donald E. Speech Understanding Through Syntactic and Semantic Analysis. Advance Papers, International Joint Conference on Artificial Intelligence, Stanford, California, 20-23 August 1973. Stanford Research Institute, Menlo Park, California, 208-215.

Walker, Donald E. Speech Understanding, Computational Linguistics, and Artificial Intelligence. In Computational and Mathematical Linguistics, Proceedings of the International Conference on Computational Linguistics, Volume I. Edited by Antonio Zampolli. Casa Editrice Leo S. Olschki, Firenze, 1973.

Walker, Donald E. The SRI Speech Understanding System. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE New York, 1974, 32-37.

Becker, Richard, and Poza, Fausto. Acoustic Processing in the SRI Speech Understanding System. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 188-192.

Paxton, William H., and Robinson, Ann E. A Parser for a Speech Understanding System. Advance Papers, International Joint Conference on Artificial Intelligence, Stanford California, 20-23 August 1973. Stanford Research Institute, Menlo Park, California, 1973, 216-222.

Paxton, William H. A Best-First Parser. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 218-225.

Baranofsky, Sharon. Semantic and Pragmatic Processing in the SRI Speech Understanding System. MS, Artificial Intelligence Center, Stanford Research Institute, Menlo Park, California, March 1974.

Deutsch, Barbara G. The Structure of Task-Oriented Dialogs. Contributed Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. IEEE, New York, 1974, 250-254.

Robinson, Jane J. Performance Grammars. Invited Papers, IEEE Symposium on Speech Recognition, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15-19 April 1974. To be published by Academic Press, New York, 1974.